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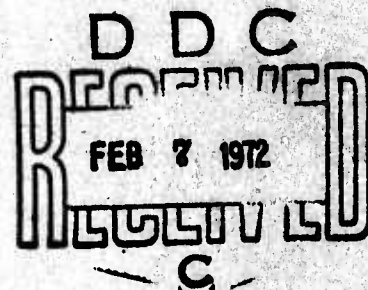
Report 2017

**PORTABLE PRESSURE-REGULATION STATION  
FOR CRITICAL DOWNHILL SECTIONS OF  
6-, 3-, AND 12-INCH MILITARY FUEL PIPELINES**

by

H. N. Johnston

November 1971



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**U. S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT CENTER  
FORT BELVOIR, VIRGINIA**



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**U. S. ARMY MOBILITY EQUIPMENT  
RESEARCH AND DEVELOPMENT CENTER  
FORT BELVOIR, VIRGINIA**

**Report 2017**

**PORTABLE PRESSURE-REGULATION STATION  
FOR CRITICAL DOWNHILL SECTIONS OF  
6-, 8-, AND 12-INCH MILITARY FUEL PIPELINES**

**Task 1J664717DL4124**

**November 1971**

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**The Commanding Officer  
U. S. Army Mobility Equipment Research and Development Center**

**Prepared by**

**H. N. Johnston  
Fuels Handling Equipment Division  
Mechanical Technology Department**

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## **SUMMARY**

The U. S. Army Mobility Equipment Research and Development Center (MERDC) has sponsored the design of a portable regulating station for critical downhill sections of 6-, 8-, and 12-in. military petroleum fuel pipelines. The design work was undertaken in response to a Department of Army (DA) Approved Small Development Requirement (SDR) for a family of pressure-regulating equipment for 6-, 8-, and 12-in. military petroleum product pipelines. The design was accomplished by Williams Brothers Engineering Company, Resource Sciences Center, under Contract DAAK02-70-C-0119.

The designed pressure-regulating station consists of four major components:

- a. A pressure-reducing control to regulate downstream pressure.
- b. A back-pressure control to regulate upstream pressure.
- c. Excess-flow control to shut off flow when the design rate is exceeded.
- d. A safety relief control to protect the station from overpressure.

The individual control components are not new or unusual in principle, but combining them into a single control system operating solely on pipeline hydraulic pressure, and unattended, is unique. The manpower, equipment, and procedures for installing and operating the designed system are described and discussed.

The report concludes that:

- a. All essential Army (SDR) requirements for a military, pressure-regulating station can be satisfied with the designed military regulating station.
- b. The primary military feature of the designed pressure-regulating station is that it can be utilized worldwide; a ready-to-install pressure-regulating station eliminates the necessity for custom design for each location.
- c. The workability of the designed military pressure-regulating station has been partially verified by the installation and operation of a commercial design of similar configuration.
- d. The designed pressure-regulating station should be satisfactory for military use.

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13. ABSTRACT The purpose of this report is to explain in detail the design, construction, and proper use of a pressure-regulating system. Investigations of the characteristics of the Rockwell Model 503 control valve revealed that one 3-in. Rockwell Model 503 control valve could be used to control the four pipeline cases of operation. By equipping the 3-in. Rockwell Model 503 control valve with two excess-flow pilots, the need for two orifices is avoided. It is recommended that certain tests be conducted to verify calculated relationships between the flow rate and the orifice differential pressure which actuates the excess-flow pilots. Detailed procedures are presented for the location, installation, and operation of the pressure-regulating systems. A calibration test is recommended to obtain calibration charts that will aid in adjustment of the system. An explanation is given for the requirements for flow rate control and pressure relief at terminals and for high-discharge pressure-shutdown controls on pumps. Operating requirements are also explained. Estimated cost and weight of the portable pressure-regulating station is included. The report concludes that: a. All essential Army (SDR) requirements for a military, pressure-regulating station can be satisfied with the designed military regulating station. b. The primary military feature of the designed pressure-regulating station is that it can be utilized world-wide; a ready-to-install pressure-regulating station eliminates the necessity for custom design for each location. c. The workability of the designed military pressure-regulating station has been partially verified by the installation and operation of a commercial design of similar configuration. d. The designed pressure-regulating station should be satisfactory for military use.			

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## **FOREWORD**

Authority for the development of a portable regulating station for critical downhill sections of 6-, 8-, and 12-in. military petroleum fuel pipelines is contained in Task 1J664717D59206, "Family of Pressure-Regulating Equipment, 6-, 8-, and 12-in. Military Petroleum-Products Pipelines."

The work was conducted during the period of November 1969 to September 1970.

The following MERDC personnel have been actively engaged in work on the project:

**Onshore Fuel Systems Branch:**

N. A. Caspero, Chief.

Robert Ray, formerly Project Engineer.

F. N. Johnston, Project Engineer.

The author wishes to acknowledge the assistance provided by Mr. Myron Wier, Williams Brothers, Resource Sciences Center, in furnishing data and guidance in the technical aspects connected with the design of a military pressure-regulating station.

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**PORTABLE PRESSURE-REGULATION STATION  
FOR CRITICAL DOWNHILL SECTIONS OF  
6-, 8-, AND 12-INCH MILITARY FUEL PIPELINES**

**I. INTRODUCTION**

1. **Subject.** This report describes and discusses the development of a military, portable, pressure-reducing station for critical downhill sections of 6-, 8-, and 12-in. military fuel pipelines. The pressure-regulating station incorporates a single piston-type valve regulated by an assembly of control valves to make it functional. The pressure-regulating station is designed to function during conditions as follows:

- a. Pipeline system during startup.
- b. Pipeline system during shutdown.
- c. Normal flow.
- d. Emergency flow.
- e. Excess flow (line break).
- f. Shutdown (static).

The primary characteristics that are required of military pressure-reducing stations but not of a commercial system are:

- a. The envelope size and weight are limited so that it is portable.
- b. The same components in the station must be used in various worldwide locations and environments.
- c. The station must be capable of being rapidly installed using Army manpower and equipment.
- d. Maintenance must be minimal and performed with minimum use of special equipment.
- e. The station must be able to operate unattended and without an external power source.

**2. Background.** Developments leading to the pressure-regulating station follow.

**a. Need for a Military System.** Military pipeline installations during World War II revealed a need for pressure regulation when petroleum fuel pipelines were constructed over the Himalaya Mountains in the China-Burma Theater and in mountainous terrain such as that found in Northern Italy.

In Army pipelines, lightweight steel tubing is coupled as the primary method of construction. Coupled pipelines are preferred in the military services over welded pipelines because of their light weight and the lack of trained pipeline welders. Army Technical Manual 5-343, "Military Petroleum Pipeline Systems," states the safe working pressures of standard military lightweight steel tubing as follows:

Nominal Line Size (In.)	Safe Working Pressure (psi)
6	600
8	500
12	400

Technical Manual 5-343 lists the working pressures of standard weight API pipe as follows:

Nominal Line Size (In.)	Safe Working Pressure (psi)
6	1200
8	1000
12	900

In 1953, the U. S. Army Engineer Research and Development Laboratories (USAERDL) at Fort Belvoir, Virginia, initiated a study of the problem of military pipeline pressure regulation requirements. Approximately 22 manufacturers were contacted to determine commercial availability of suitable pressure-regulating equipment. At that time, one valve manufacturer's control equipment appeared suitable for application to a military, portable, pressure-regulating station. Evaluation tests on these valves began in October 1954 and revealed that the rubber expandable tubes, which were the prime components of the valves, would not operate effectively at subzero temperatures; and a low-temperature, fuel-resistant rubber is not available.

In 1956 and 1957, an engineering company was contracted by USAERDL to investigate, evaluate, and select suitable pressure-regulating equipment. Again, the

study evolved in such a way that the same equipment was used that was selected in the 1953 study and again the equipment was discounted due to ineffective operation at subzero temperatures. During this study, assistance was solicited from 41 valve manufacturers, 35 pipeline operators, 5 pipeline design and engineering organizations, and the American Petroleum Institute Committee on Pipeline Transportation. The general comments received from these organizations indicated the following:

- (1) The type of pressure regulation utilized on commercial overland pipelines is determined by the requirements of a specific location and application.
- (2) Each design is peculiarly suited for that location.
- (3) No two designs are necessarily alike.

The design restraints or requirements for commercial applications are therefore somewhat different from the initial military objective of using one standard pressure-regulating-station assembly for all requirements. It is noteworthy that, subsequent to this period (1956-57), the military objective changed to one of applying a variety of pressure-regulating stations to meet all military requirements, rather than one regulating station for all military requirements. During this 1956-57 study, correspondence from a leading pipeline design and construction firm indicated that it was being faced with a complex pressure-regulating problem concerning a proposed pipeline over rugged terrain from Sicasica, Bolivia, to Arica, Chile. The remoteness of this pipeline indicated a need for pressure-regulating stations that were operated solely by hydraulic pressure and were self-regulated, automatic, and unattended.

In June 1960, the Petroleum Equipment Branch (USAERDL), completed a study to investigate the requirements, methods, and equipment for pressure regulation in long, downhill, military-pipeline sections or where the pipeline profile forms a deep gorge. Included in this study was additional testing and evaluation of an improved version of the regulating valve that was evaluated in the two previous studies of 1953 and 1956-57, with the results, as previously concluded, that the valve would not operate effectively at subzero temperature.

The 1960 study was effective in establishing preliminary design criteria for pressure-regulating equipment, and formed the basis for the establishment of a Department of the Army Approved Small Developments Requirement (SDR) for a family of pressure-regulating equipment for 6-, 8-, and 12-in. military petroleum-products pipelines. That SDR was proposed in early 1965 by the U. S. Army Combat Developments Command (USACDC), Fort Belvoir, and was approved by DA, Office of the Chief of Research and Development, on 22 October 1965.

**b. Commercial Methods.**

(1) Use of welded pipeline construction exclusively, which inherently will withstand higher pressure than coupled lightweight tubing.

(2) Change to a heavier wall pipe in critical areas of a pipeline where excessive pipe pressures could be encountered.

(3) Use of a smaller diameter pipe while maintaining or increasing the wall thickness to accommodate higher pressures associated with critical sections of pipeline.

(4) Installation of a relief valve and piping to a storage tank in areas of a pipeline where critical pressures could be encountered. Whenever excessive pressures occur, product is relieved to storage and later pumped back into the pipeline.

(5) Control of pipeline pressure limits with pressure-regulating valves or shutoff valves that are powered with an external source of power, such as electricity or compressed air.

(6) Control of pipeline pressure limits with pressure-regulating valves that are powered with the hydraulic pressure of the product being conveyed in the pipeline.

**c. MERDC Development Effort.** The groundwork for development of pressure-regulating equipment for military field pipeline systems by MERDC was laid in 1953 when Mr. S. J. Holzweig, Project Engineer in the Petroleum Equipment Branch, USAERDL, initiated a study of this problem. In 1954, before that study was completed, Mr. Holzweig resigned his position and no conclusions were drawn. In April 1957, a report under Project 8-53-03-101 was prepared by Arland Engineering Company and submitted to the Chief of Engineers, U. S. Army, under the title "Pressure-Regulating Valves for Military Pipelines." This report recommended a valve, but its minimum operating temperature of 0° F seriously limited the number of geographical areas of the world in which it could be utilized effectively.

Also in June of 1960, Technical Report 1639 TR, "Pressure Regulation in Long Downhill Sections of a Military Pipeline," was prepared by M. A. Pachuta, Petroleum Equipment Branch, USAERDL. It concluded that additional study, design, and development were required to obtain suitable pressure-regulating equipment.

In November 1965, the Department of the Army approved a Small Development Requirement for a "Family of Pressure-Regulating Equipment, 6-, 8-, and 12-In., Military Petroleum-Products Pipelines," a formal document which sanctioned MERDC's development work.

In October 1969, Williams Brothers Engineering Company, Resource Sciences Center, was awarded Contract DAAK02-70-C-0119 for the design of portable pressure-regulating stations for critical downhill sections of 6-, 8-, and 12-in. military petroleum fuel pipelines. In September 1970, Williams Brothers Engineering Company, Resource Sciences Center, submitted its final report (1)\*, including drawings and specifications, on the pressure-regulating stations.

Funding difficulties at this time are preventing the fabrication and testing of the designed military pressure-regulating station. However, Williams Brothers Engineering Company has built and installed a commercial station which is a modified version of the military station.

In 1970, MERDC recommended that U. S. Army Combat Developments Command be contacted to review the requirements for a family of pressure-regulation stations. No reply has been forthcoming.

## II. INVESTIGATION

3. **Description.** A pressure-regulating station is an assembly of valves, controls, and an orifice that provides a pipeline for overpressurization during operating or shut-down conditions. An artist's concept is illustrated in Fig. 1. The military pressure-regulating station as discussed herein consists of four major components.

- a. One 3-in. Rockwell Model 503 Valve. A main control valve.
- b. One 2-in. Rockwell Model 503 Valve. A safety relief valve.
- c. One 6-in. Orificemaster. An excess-flow control.
- d. Pilot Valves. Two Rockwell Model 2760 pilot valves, two Rockwell Model 2780S pilot valves, and one Rockwell Model 2750 pilot valve. These valves sense pressure changes and actuate the 2- and 3-in. Rockwell valves.

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\*Numbers appearing alone in parentheses in the text refer to "LITERATURE CITED," p. 59.



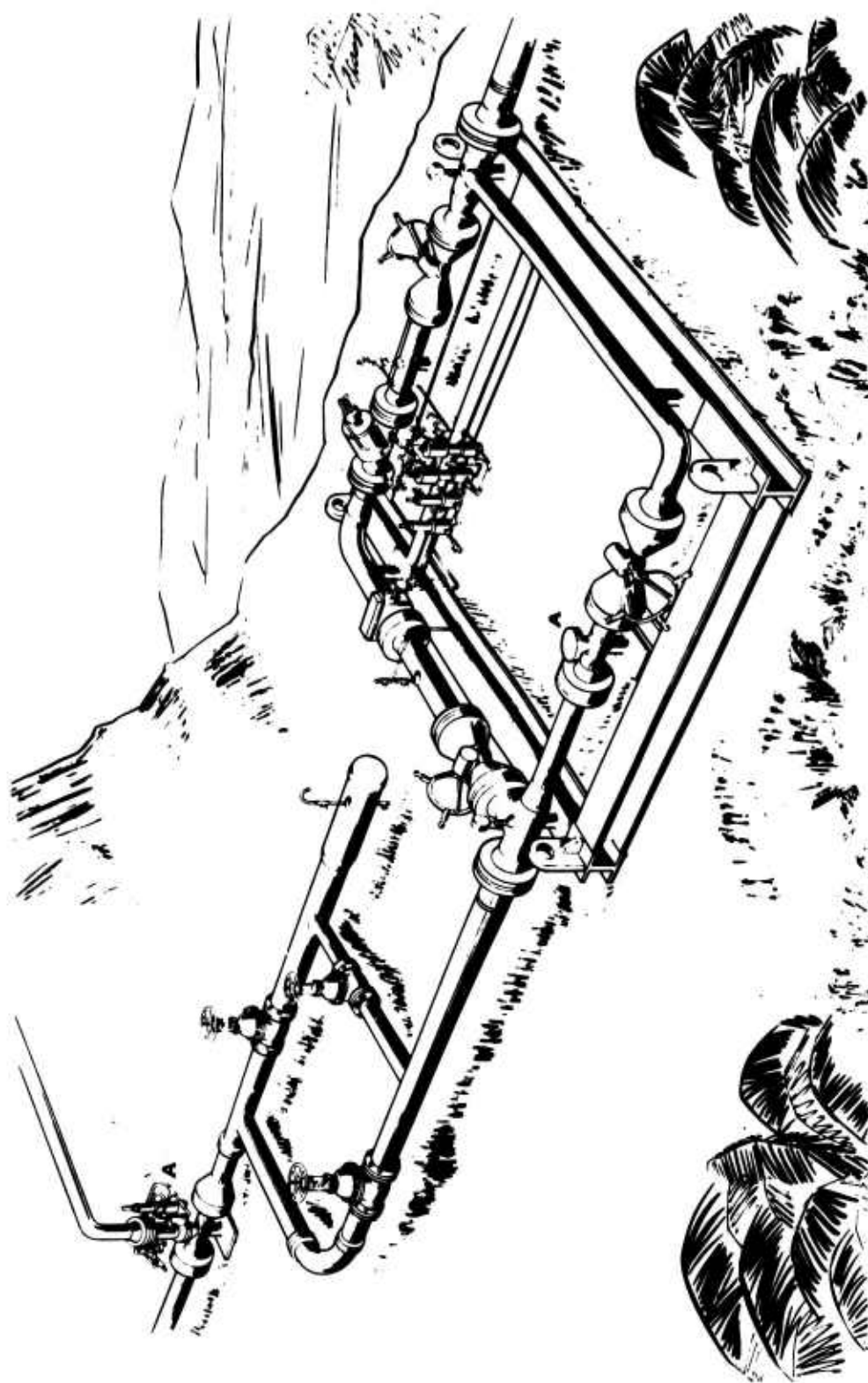


Fig. 1. Artist's concept of a pressure-regulating station.

These components are further described for the MERDC pressure-regulating station:

a. **Two- and Three-inch Rockwell Model 503-I Control Valves.** These valves are manufactured by Rockwell Manufacturing Company, Pittsburgh, Pennsylvania, and have 600-lb, ASA, raise-faced flanges on each end. Each valve has a steel body and is rated for 1440 psi working pressure. Each valve is equipped with a stainless-steel piston, low-temperature O-rings ( $-50^{\circ}\text{F}$  to  $+150^{\circ}\text{F}$ ), and ductile-iron indicating extension.

b. **Orificemaster.** Flanged cast steel, 6-in., 600-lb, ASA, with orifice plate 6.065-in. ID by 3.803-in. bore.

c. **Rockwell Model 2750 Pressure-Reducing Pilot.** This valve is manufactured by the Rockwell Manufacturing Company of Pittsburgh, Pennsylvania, and has steel bodies rated for 1440 psi working pressure. Each pilot has stainless-steel trim and special low-temperature O-rings ( $-50^{\circ}\text{F}$  to  $150^{\circ}\text{F}$ ). Each pilot is equipped with a dial indicator for pilot position and a spring with range of 50 to 1000 psi.

d. **Rockwell Model 2760 Back-Pressure Pilot.** Same description as Model 2750 except spring range is 300 to 1500 psi.

e. **Rockwell Model 2780S Flow-Rate Pilot.** This valve is manufactured by the Rockwell Manufacturing Company of Pittsburgh, Pennsylvania, and has steel bodies rated for 1440-psi working pressure. Each pilot has stainless-steel trim and special low-temperature O-rings ( $-50^{\circ}\text{F}$  to  $+150^{\circ}\text{F}$ ). Each pilot is equipped with a spring of 5 to 100 psi. Each pilot is normally open and trip-lever operated to close at set differential pressure and remain closed until manually reset.

4. **Requirements.** In general, the military pressure-regulating station is required to protect the pipeline from excessive pressure, both upstream and downstream, be easily handled by military field-transportation facilities, be easily installed and maintained, and be operational in all weather conditions. The SDR sets forth more specific requirements for the military version.

The SDR requirements are summarized and presented in essential categories below:

a. **Essential Military Characteristics.**

(1) **Operational Characteristics.**

(a) Be capable of being installed and operated in climatic categories 1 through 6 as defined in Army Regulation 70-38.

- (b) Be capable of operating unattended.
- (c) Be capable of blocking flow to minimize fuel loss in event of line break.
- (d) Be capable of protecting the pipeline from excess line pressure which results from opening and closing block valves either up or downstream.
- (e) Be capable of protecting the pipeline from excessive line pressure which results from starting and stopping pumps either upstream or downstream.
- (f) Be designed to permit passage of pipeline scrapers or incorporate provisions for receiving and sending scrapers.
- (g) Be capable of operating to protect the pipeline from excessive pressure created by static, steady-state flow, and transient flow conditions.
- (h) The weight of the pressure-regulating equipment will be consistent with present-day scientific knowledge. Dependable, trouble-free service is the first consideration when this development is pursued.
- (i) Configuration of the pressure-regulating equipment will be such that the installed facilities will present as low a silhouette as possible.
- (j) The equipment shall be suitable for transport by vehicles available within the Type Field Army.
- (k) Be designed so that pressure losses throughout the pressure-regulating equipment are minimized.
- (l) Allow for thermal expansion and contraction of line fill.
- (m) Except for expendable interior components, the pressure-regulating equipment shall have an effective life of at least 5 years of continuous or intermittent service under the environmental categories (1 through 6) as defined in Army Regulation 70-38.

**(2) Maintenance Concept.**

- (a) Design will include all ease-of-maintenance features which are consistent with performance and reliability.

(b) Maximum use will be made of the concept of maintenance and repair by modular replacement of assemblies of subassemblies.

(c) Design simplicity will be such that skills and knowledge required to perform maintenance do not exceed the skill level of MOS 63E20, Quartermaster Heavy Equipment Repairman.

(d) Test and checkout methodology. No special test equipment other than pressure gages will be required.

Allowable time for diagnosing failures will be such that 90 percent of the diagnoses will be accomplished as follows:

Organization maintenance—30 minutes.

Direct support maintenance—2 hours.

Allowable time for making repair and testing corrective action will be such that 90 percent of the activities will be accomplished as follows:

Organizational maintenance—2 hours.

Direct support maintenance—4 hours.

(e) Design will incorporate go-no-go built-in checking devices wherever practical.

5. **Feasibility Study.** The first direct effort taken by MERDC to develop a military pressure-regulating station was initiated in 1960 when USAERDL requested approval of the recommendation of Report 1639-TR, "Pressure Regulation in Long Downhill Sections of a Military Pipeline." In 1965 a Department of the Army Approved Small Development Requirement (SDR) for a "Family of Pressure-Regulating Equipment, 6-, 8-, and 12-in. Military Petroleum-Products Pipelines" was issued and stated: "The technical feasibility of these items has been demonstrated by similar equipment for civilian use. There are no known technical risks that may influence the effectiveness, cost, or delivery date of the pressure-regulating equipment."

The next direct effort was taken in 1969 when Williams Brothers Engineering Company, Resource Sciences Center, was awarded a contract to establish design requirements for a military, pressure-reducing station. Williams Brothers Engineering interim technical report on the study covers the following specific methods for protecting pipelines from excessive pressures.

a. **Method 1:** Operating the pipeline only partly filled so that an open pipeline occurs on downhill sections at all times. This produces a cascading effect similar to a waterfall. In multiproduct pipelines where batch segregation is important, this operation is undesirable as it allows commingling of products. It also requires that the pipeline not operate at the full rated capability of the pipe.

b. **Method 2:** Laying heavy wall pipe in low sections of the pipeline so that the static head will not exceed the rated pressure limit of the pipe. This method is usually acceptable for minor elevation differences and short downhill grades; but, where major elevation differences and/or extended downhill grades are encountered, this method is likely to become unacceptable because of the number of different weights of pipe required. As the weight of the pipe increases, the installation and material costs increase to a point where this method becomes uneconomical.

c. **Method 3:** Pressure control which will dissipate the static head at fixed elevation intervals along the downhill grade of the pipeline. This method allows tight-line operation without the use of heavy wall pipe. It can be varied to meet changing conditions and provide additional protection against pressure surges and excessive loss of product in case of pipe failure.

The third method of operation was determined to be the most practical for use by the U. S. Army and the analysis follows:

**Concept 1: Flow chokes.** The flow-choke concept is based on the use of chokes to restrict flow and create pressure drops. The pressure drop through a choke is a function of the flow rate and the bore of the choke. The bore of the choke is fixed; therefore, any change in flow rate will result in a change in pressure drop. A choke may be sized to pass the maximum flow rate at the desired pressure drop; however, if variations are expected in flow rate, it is desirable to design a system using several chokes in parallel to handle the maximum flow rate with the capability for closing off one or more chokes for operations at lower flow rates. This may be accomplished by the use of pilot-operated valves actuated by an orifice of choke differential sensitive to the main-line flow rate. To provide protection when the system is shut down, a control valve should be added downstream of the chokes. This valve will also provide a constant downstream pressure. (Refer to Figs. 2 and 3.)

**Concept 2: Pipe loops.** The pipe-loop concept involves the installation of a sufficient length of reduced-diameter pipe to produce a head loss due to friction that will dissipate the static head during flowing conditions. In its simplest form, the pipe-loop concept provides no adjustment for variations in pressure and flow rate and no means for controlling static head when the pipeline is shut down. To add these required provisions, this concept must be made more complex.

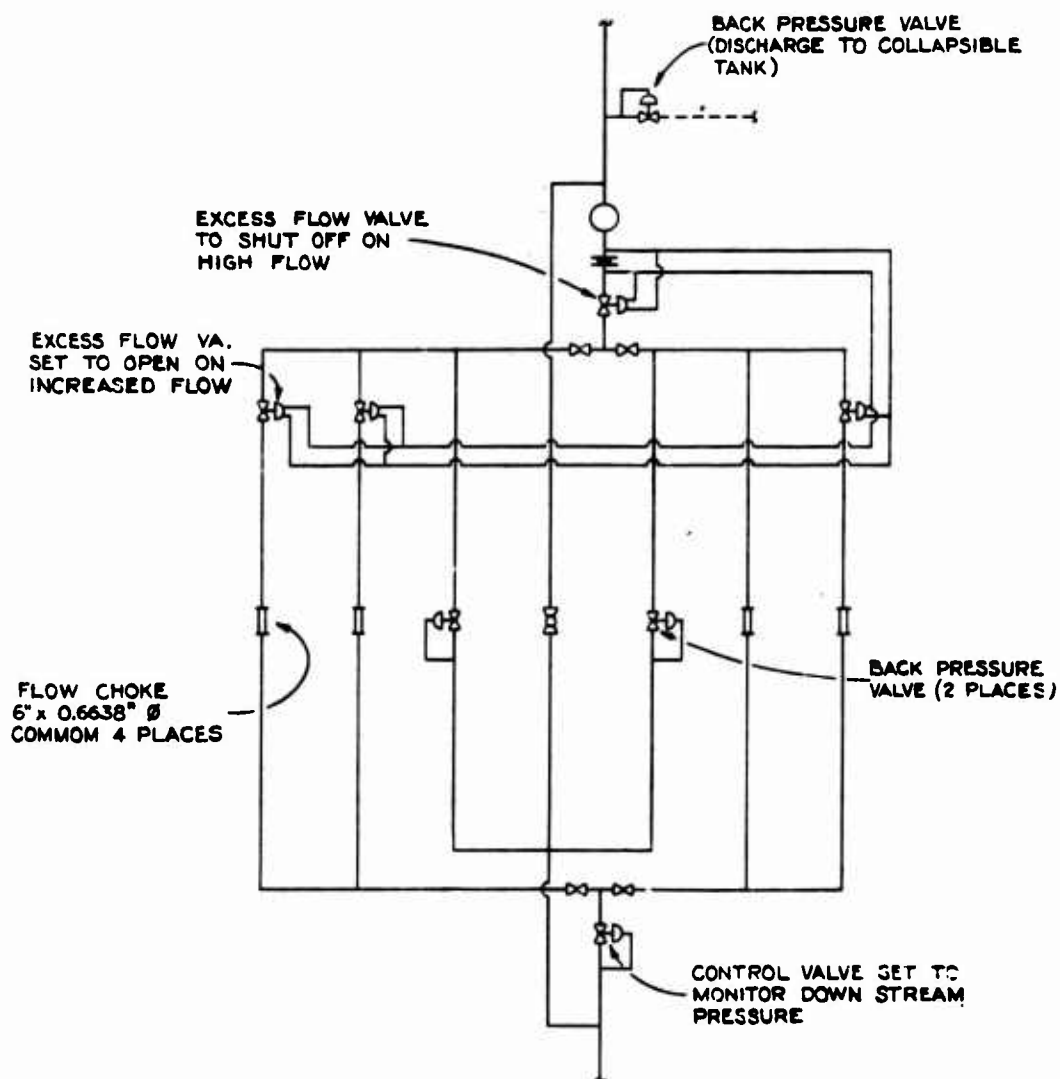


Fig. 2. Flow chokes, sketch 1.

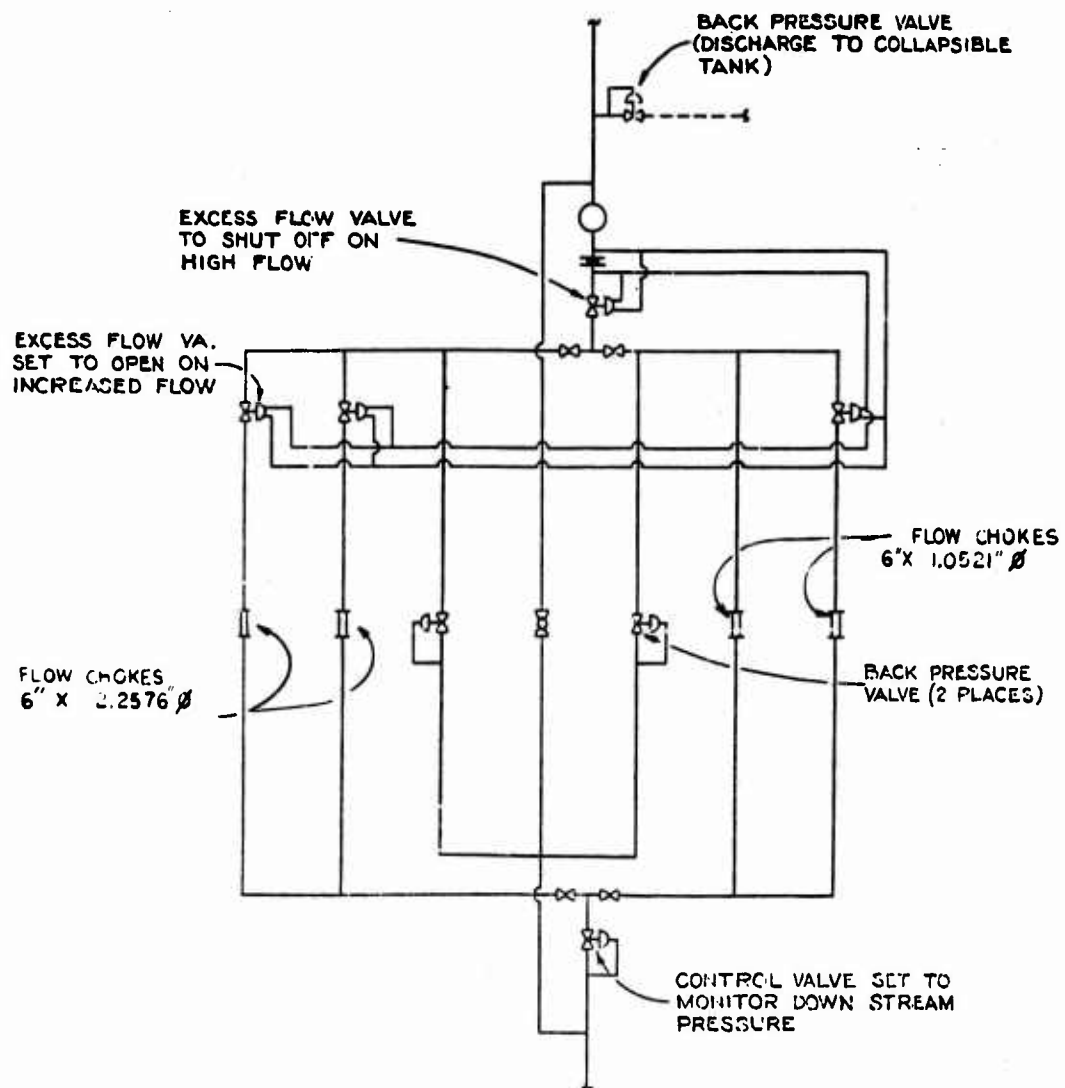


Fig. 3. Flow chokes, sketch 2.

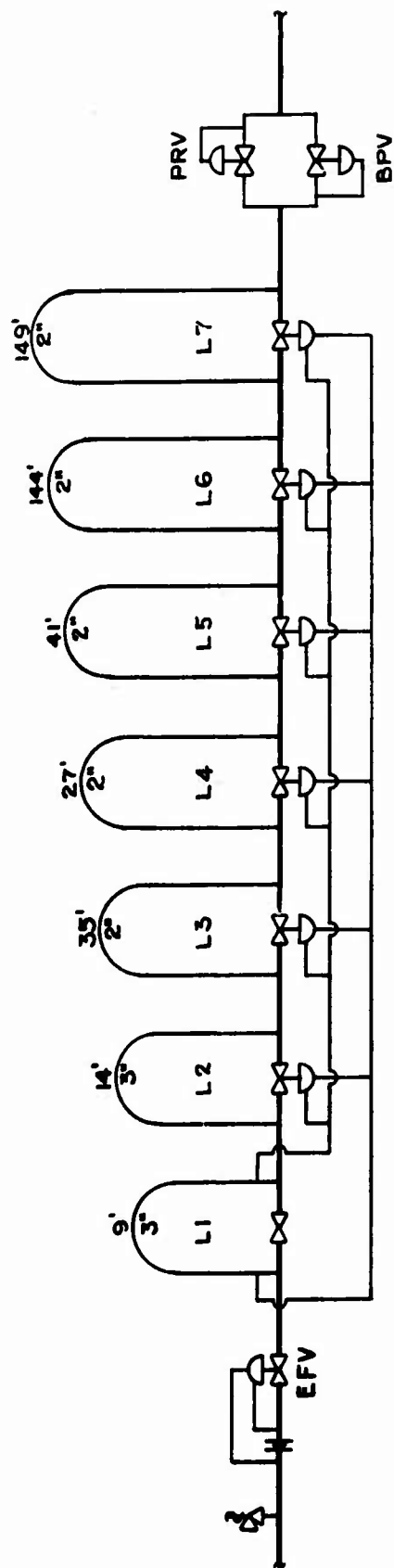


Fig. 4. Pipe loops.



To provide for variations in flow conditions, the reduced-diameter pipe may be divided into several loops of various lengths. These loops may be bypassed by using pilot-operated valves controlled by the pressure differential through a fixed orifice of another pipe loop; thus the flowing fluid is controlled incrementally. Also, the addition of control valves downstream of the loops will provide the additional controls required, including the removal of pressure fluctuations caused by incremental use of loops. (Refer to Fig. 4.)

**Concept 3: Control valves.** The control-valve concept places the entire responsibility of controlling the downstream pressure under either flowing or shutdown conditions on one or more control valves. This concept has been used on several existing pipeline systems and has been proven under operating conditions. Where conditions vary, several valves may be used in parallel to obtain the desired throughputs and pressure drops.

Control-valve systems provide continuous control of downstream pressure which can be manually adjusted. Constant downstream pressure may be maintained from a zero flow rate to the maximum designed flow rate of the control valves.

This concept may be expanded to provide a system that will perform other desired control functions, such as protecting the pipeline from overpressurization, and add flexibility of operation. Combinations of various types of commercially available and operationally proven control valves, with the necessary hydraulic-pressure-sensing devices, may be arranged to provide the required control of fluid flow and pressure regulation. (Refer to Figs. 5 through 13.) The design concept incorporating the use of pressure-control valves was determined the most practical and applicable concept for use by the U. S. Army.

Extensive exploratory engineering was performed on a wide variety of control valve styles. Different styles of control valves exhibit definite individual flow characteristics. These characteristics are determined experimentally by the manufacturer and published for use in valve selections for specific design conditions.

The desired system flow characteristics were specified under each case of operation. These characteristics were compared to the published flow characteristics of the control valves. From this comparison, it has been determined that a combination of control valves is required to meet the specified conditions. Also, it has been determined that the characteristics of individual control valves define a particular design arrangement, thus eliminating a final design configuration allowing the interchangeability of equipment from different manufacturers.

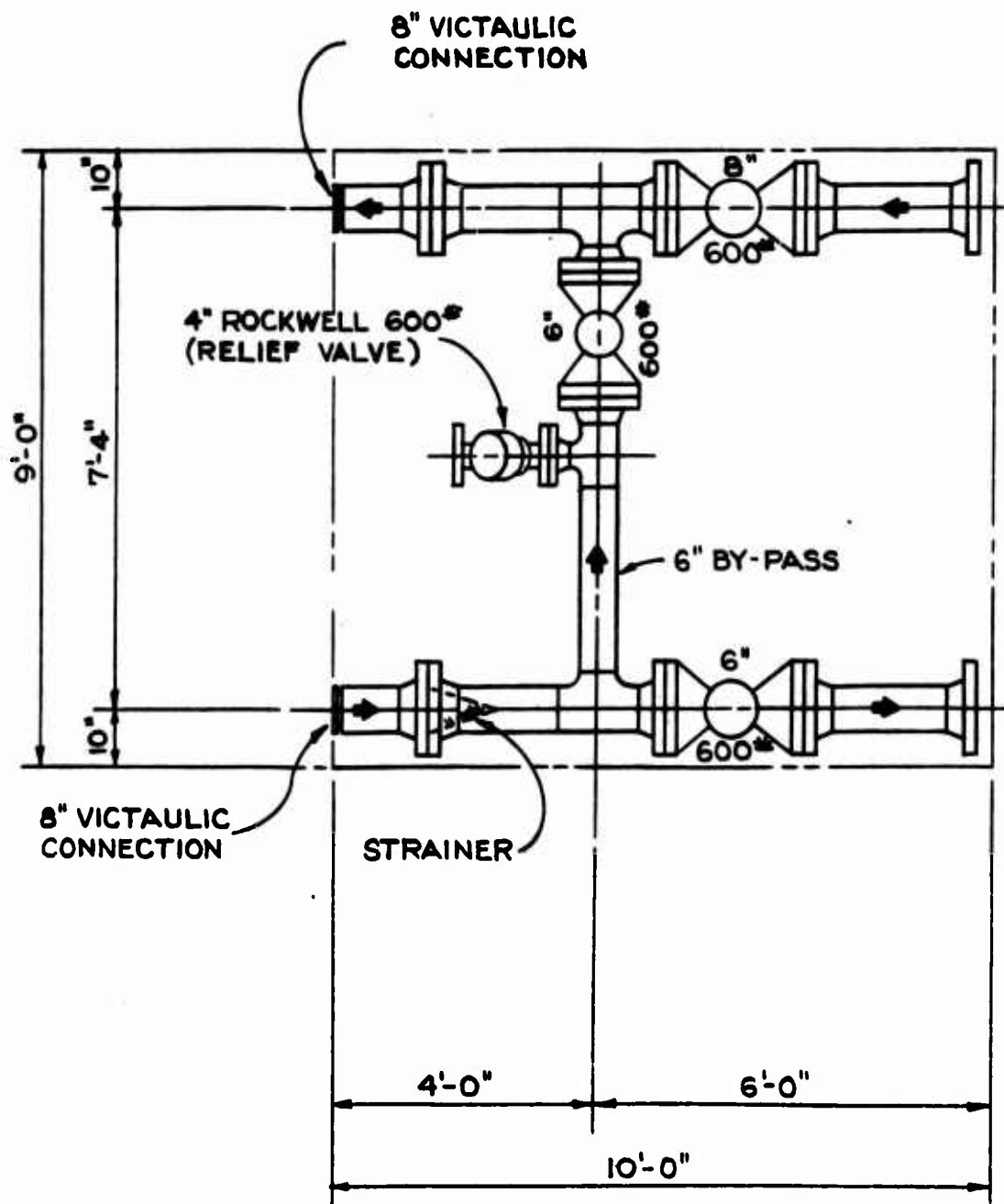


Fig. 5. Control valves, Masoneilan, 10000 Series (manifold unit).

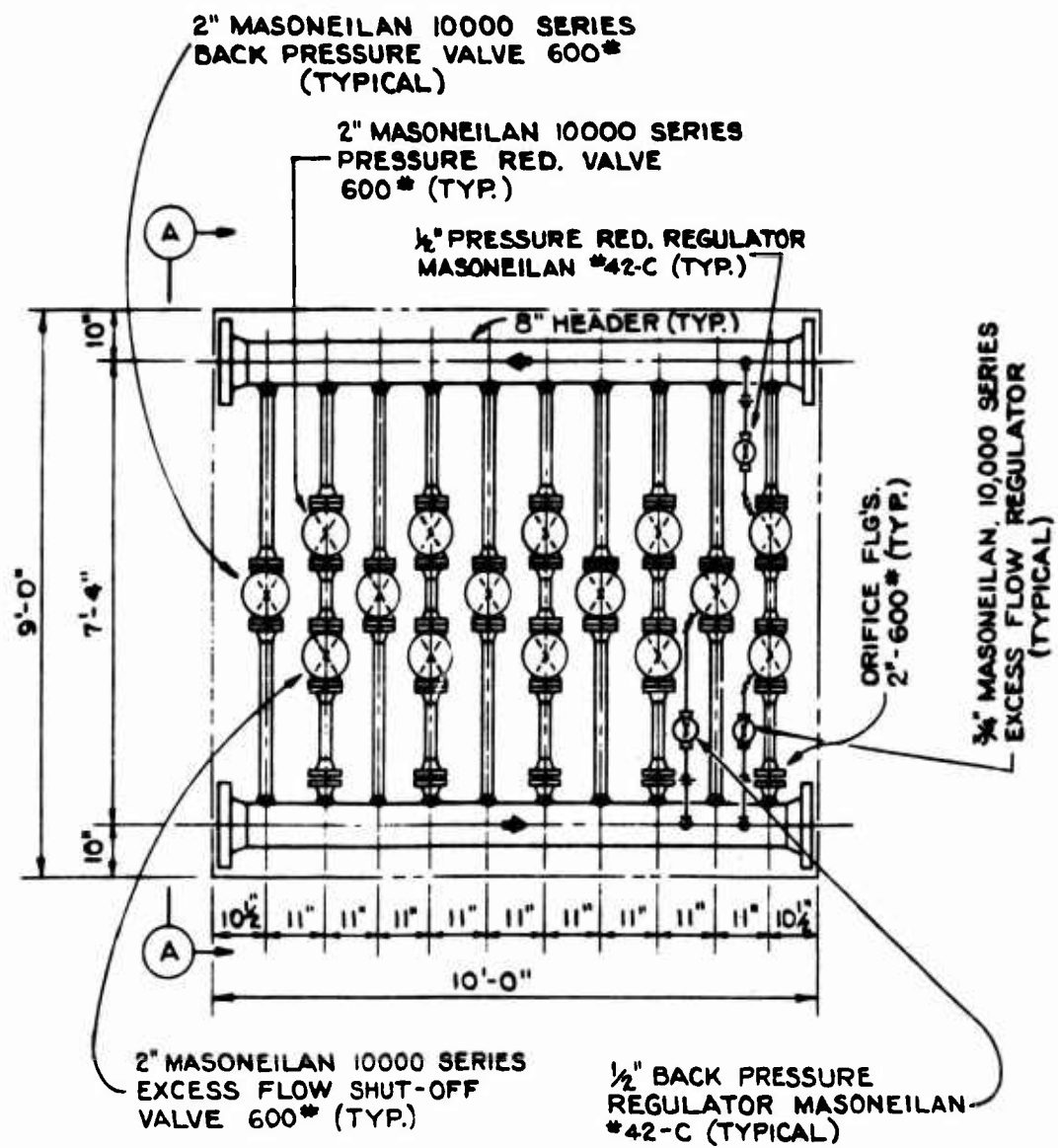


Fig. 6. Control valves, Masoneilan, 10000 series (control unit).

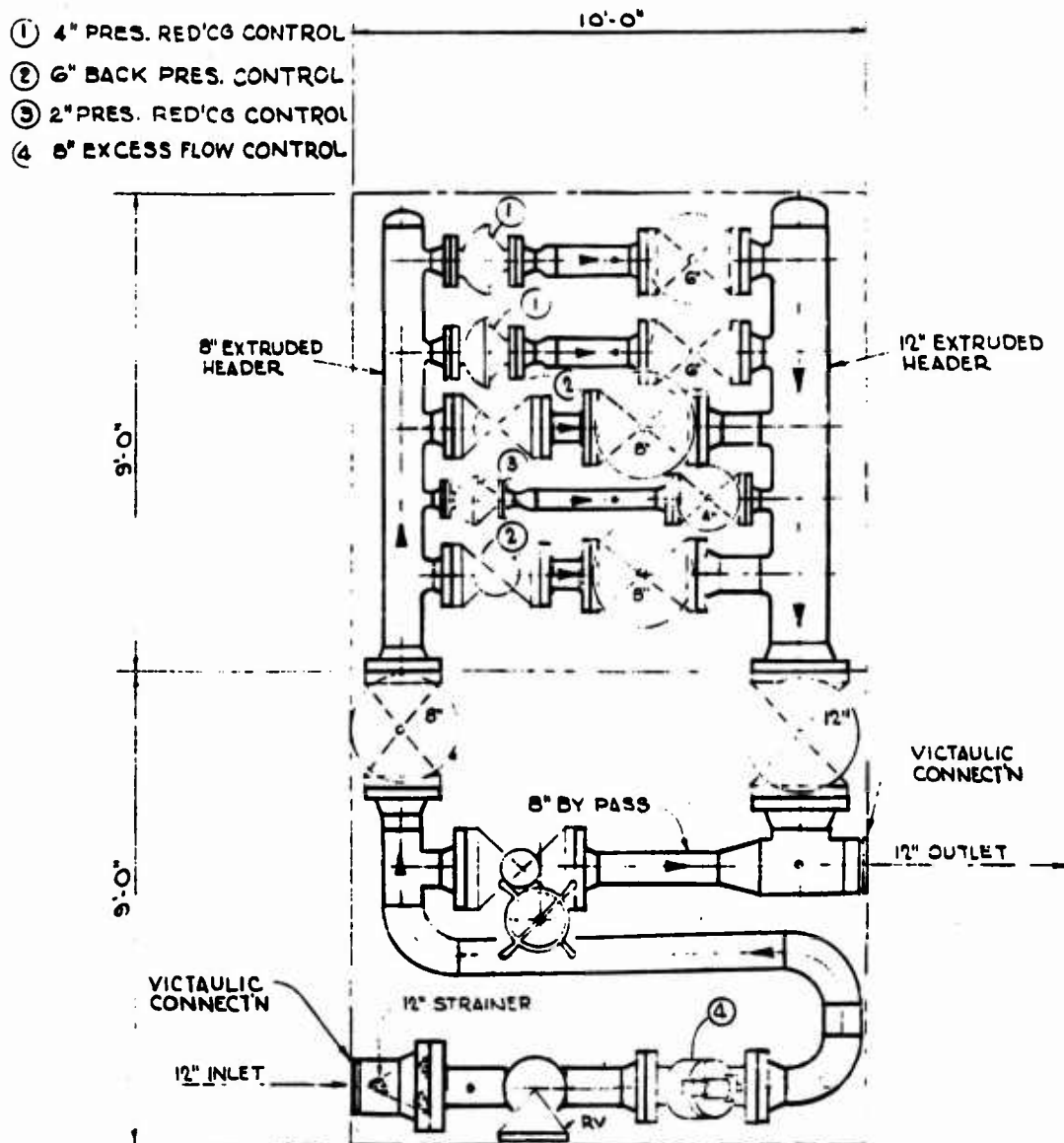


Fig. 7. Control valves, Fisher, Type 310.

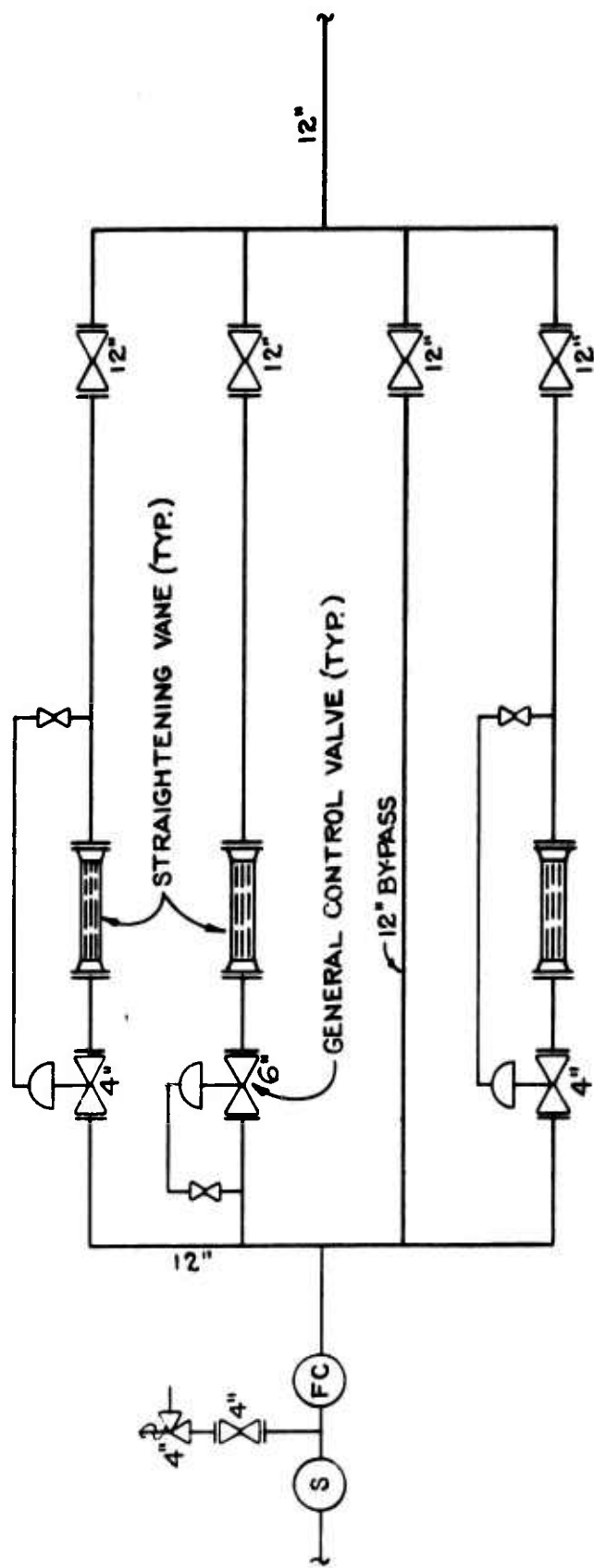
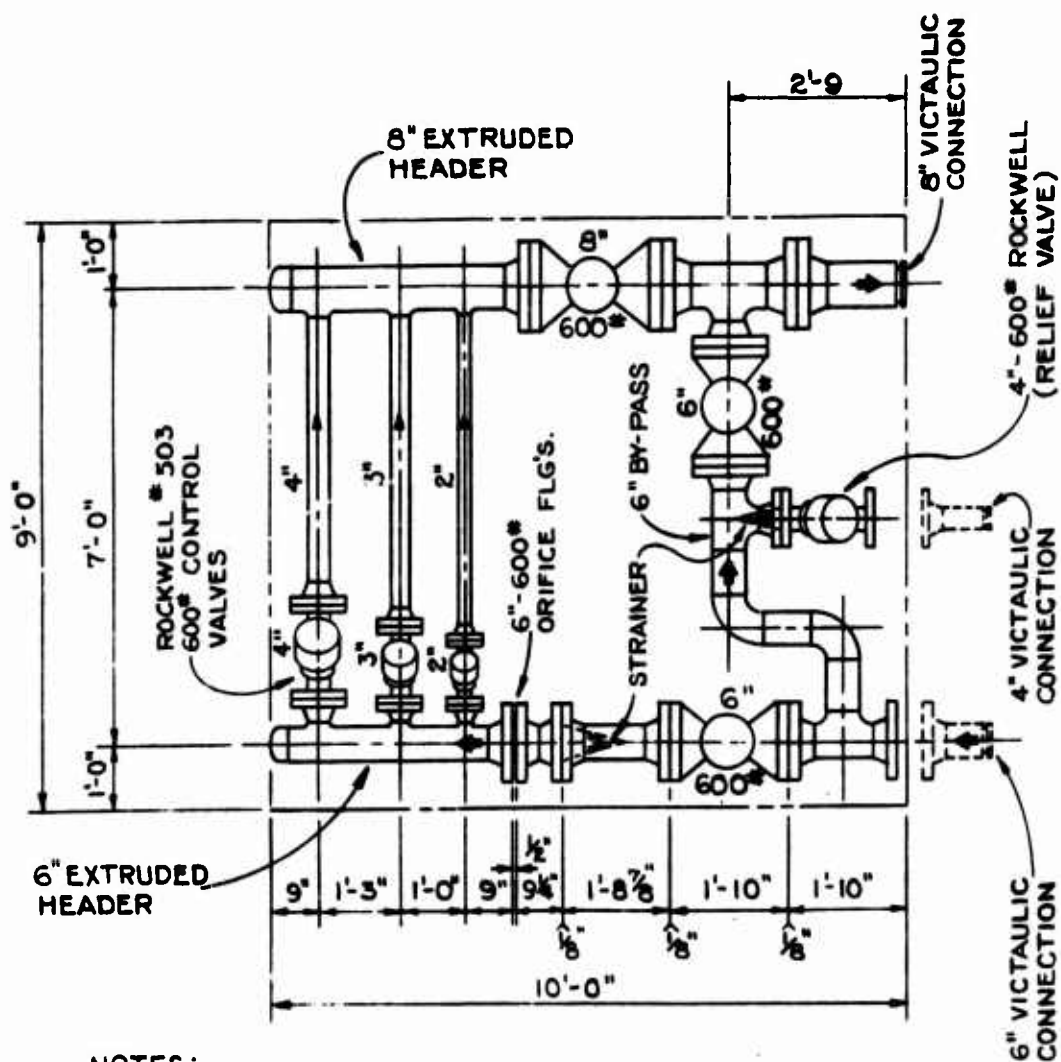


Fig. 8. Control valves, General, Model 5100.



**NOTES:**

1. ONE SKID MOUNTED ASSEMBLY REQUIRED.
2. SIZE: 9'-0" x 10'-0" x 2'-10"

Fig. 9. Control valves, Rockwell, Model 503 (control unit).

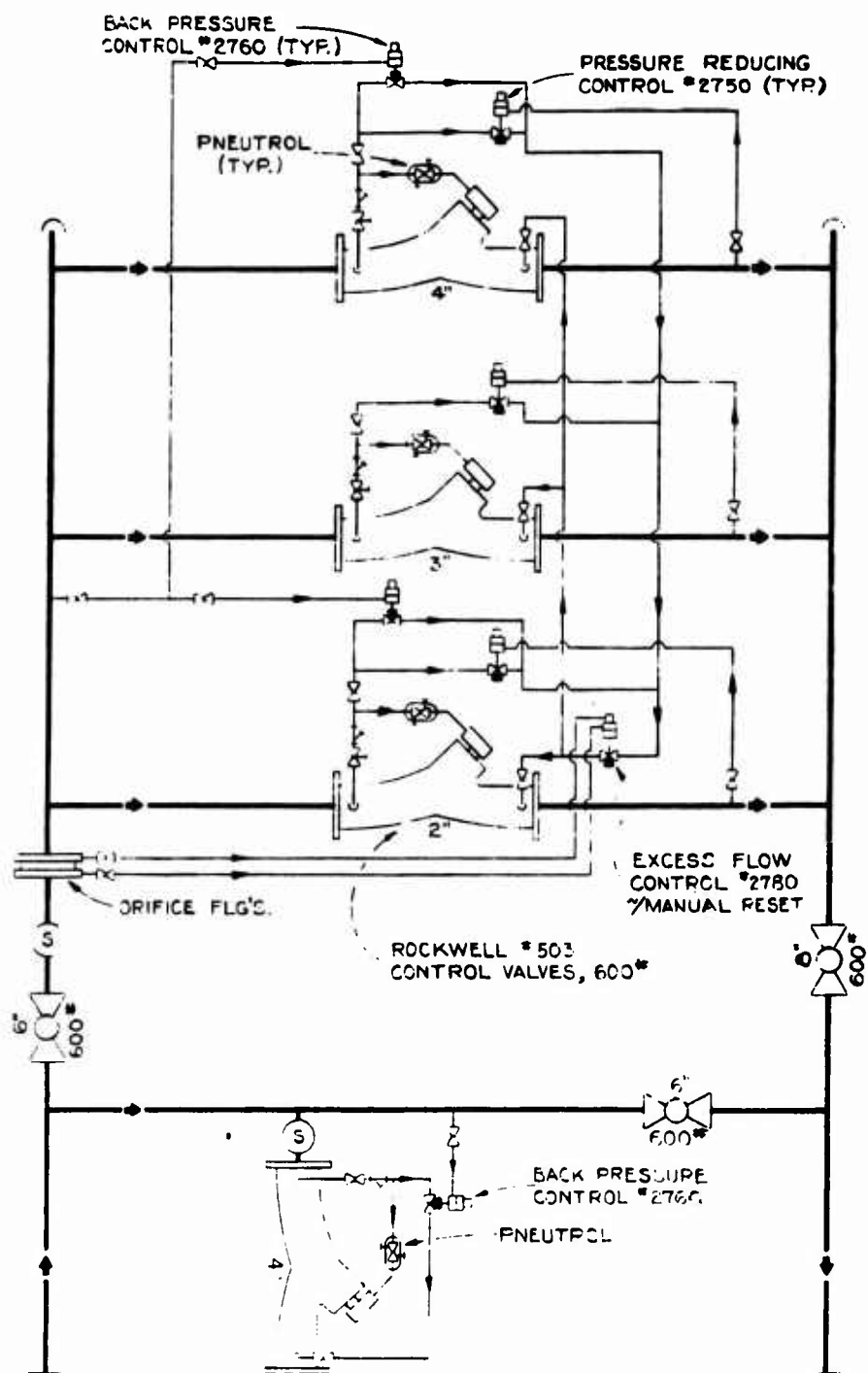


Fig. 10. Control valves, Rockwell, Model 503 (control schematic for single-pilot mounting).

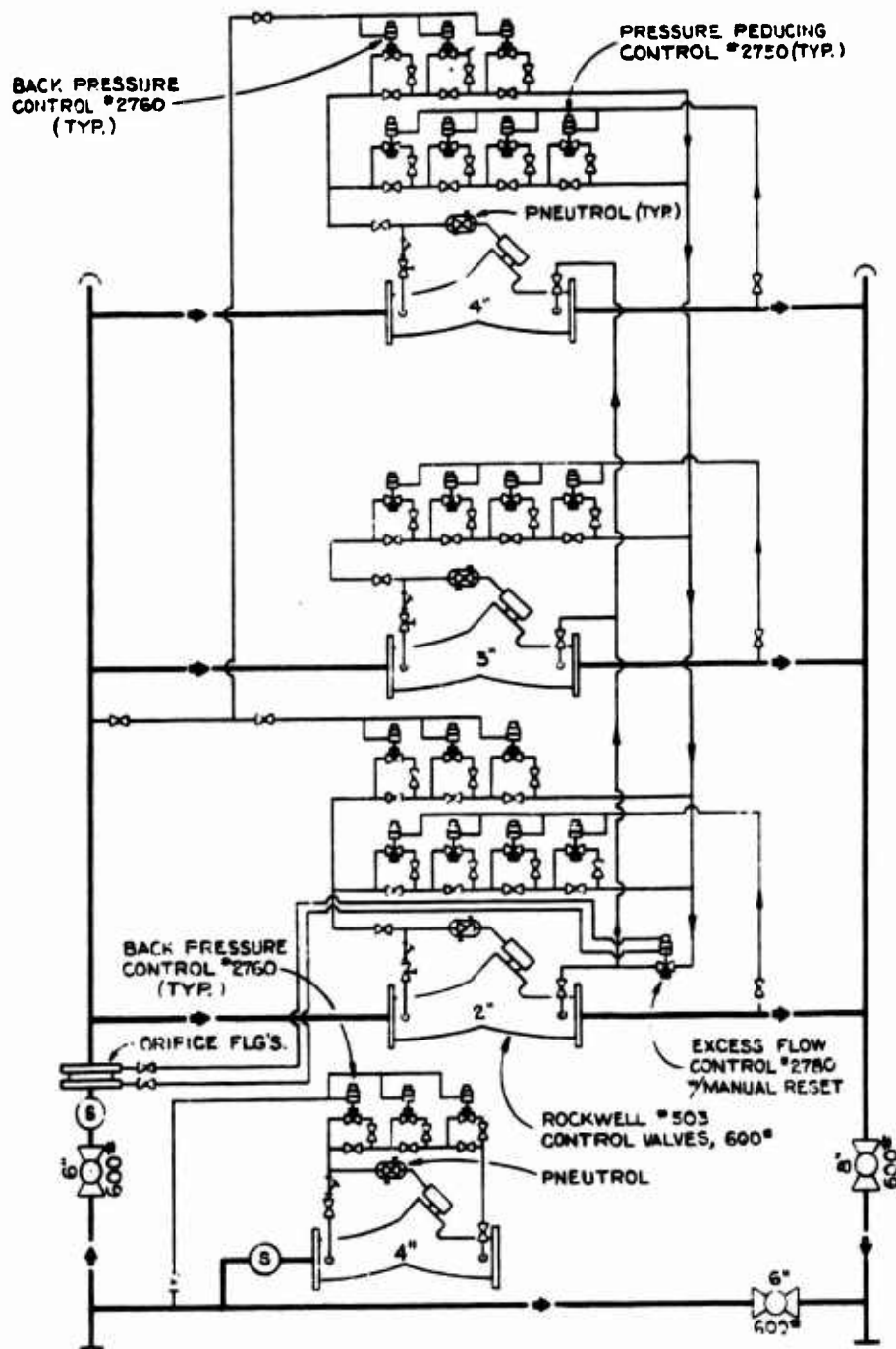
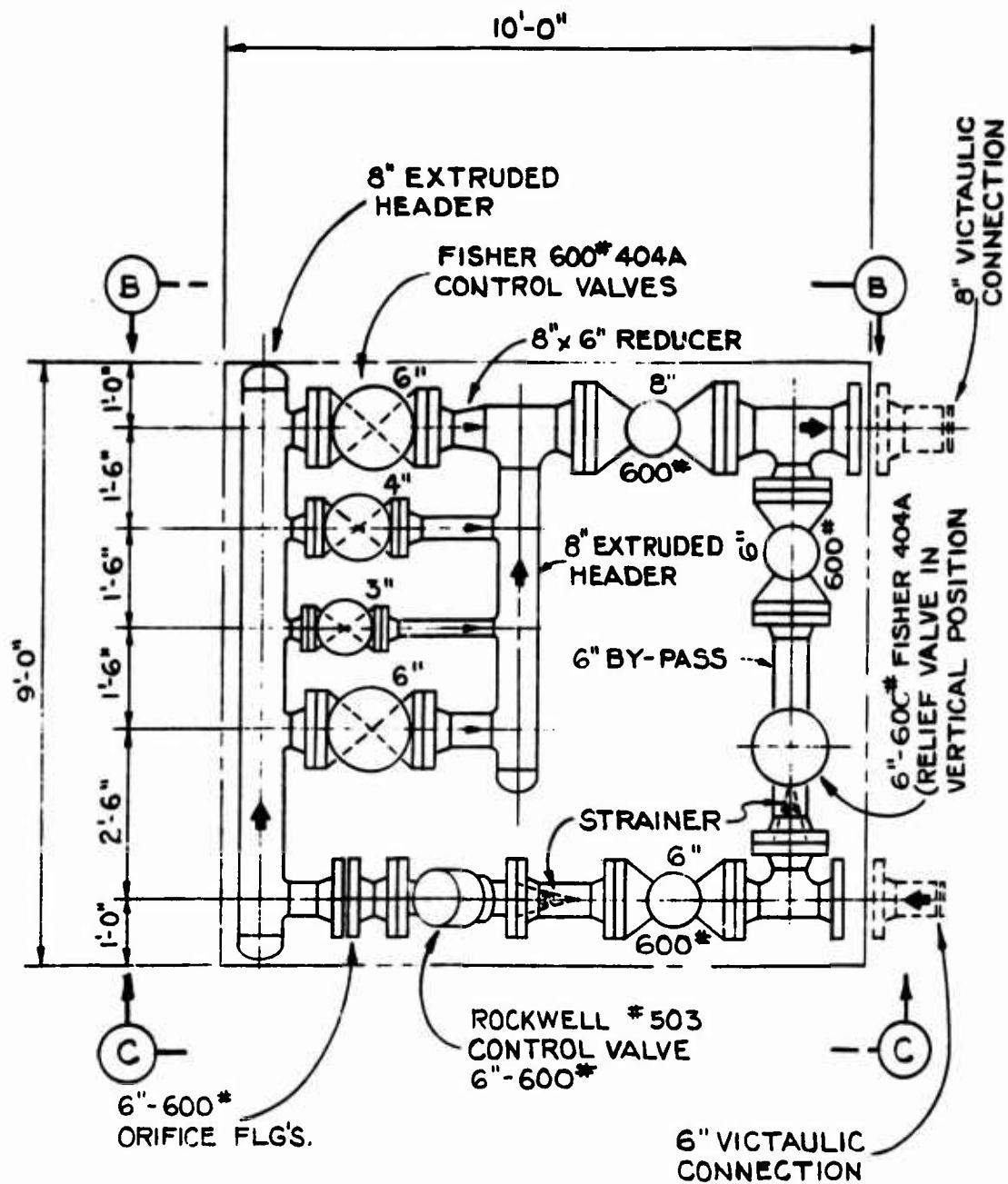


Fig. 11. Control valves, Rockwell, Model 503 (control schematic for multiple-pilot mounting).





#### NOTES

1. ONE SKID MOUNTED ASSEMBLY REQUIRED.
2. SIZE : 9'-0" x 10'-0" x 3'-10"

Fig. 12. Control valves, Fisher Type 404A (control unit).

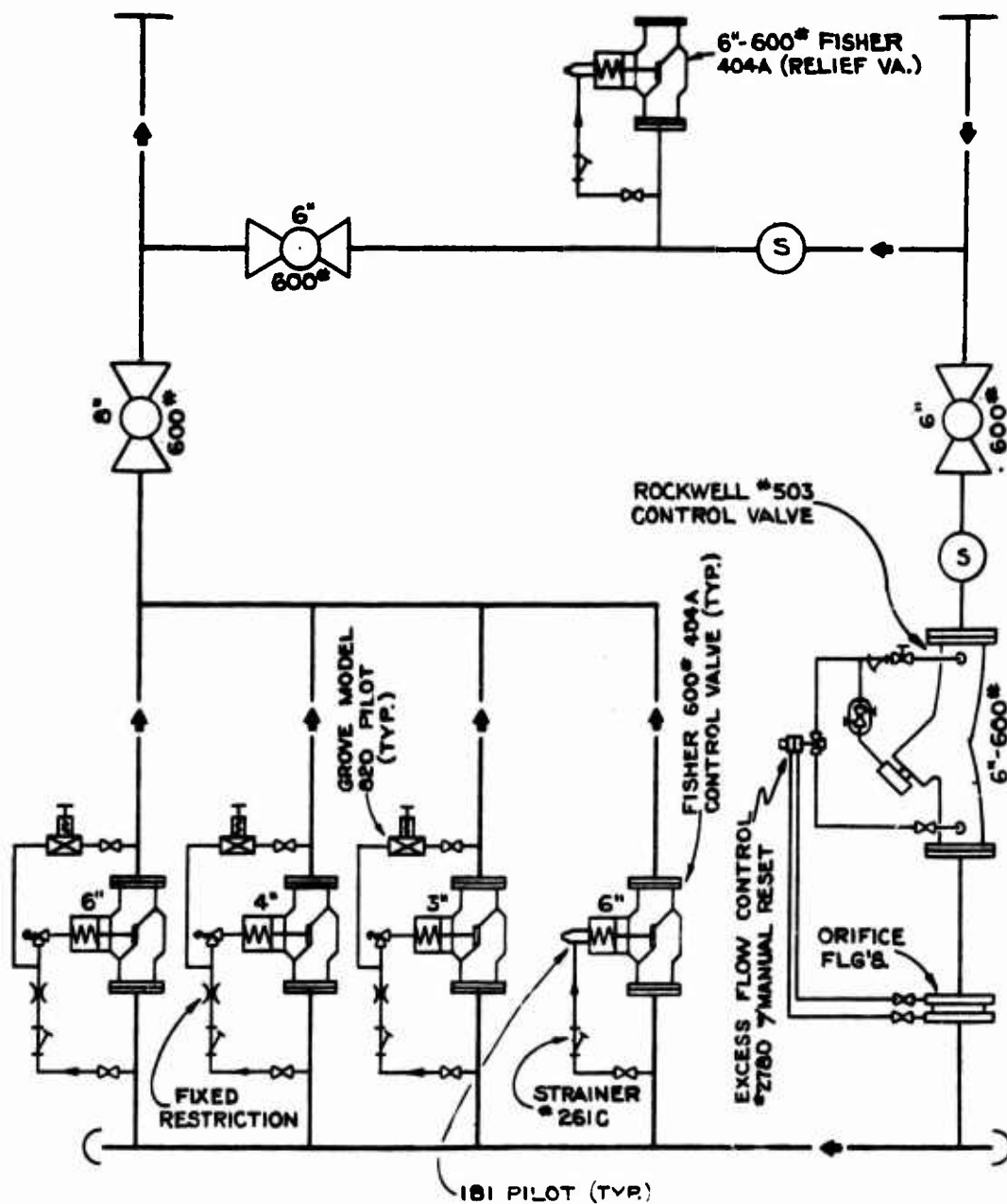


Fig. 13. Control valves, Fisher, Type 404A (control schematic).

Several design configurations were investigated using individual manufacturer's equipment as the primary control valve. Manufacturers and the respective primary control valves investigated in detail are listed below:

- (1) Worthington Controls Company  
Division of Worthington Corporation  
Norwood, Massachusetts

Masoneilan, 10000 Series

- (2) Fisher Controls Company  
Marshalltown, Iowa

Fisher, Type 310  
Fisher, Type E  
Fisher, Type 404A

- (3) General Valve Company, Inc.  
Long Beach, California

General Model 5100

- (4) Rockwell Manufacturing Company  
Pittsburgh, Pennsylvania

Rockwell, Model 503

A configuration of Masoneilan 10000 Series valves is shown on Figs. 5 and 6. A manifold unit and from one to four control units are used depending on the required operating condition. Each control unit incorporates fifteen 2-in. Masoneilan 10000 series control valves: Five for back pressure control; five for downstream pressure regulating; and five for excess flow shutoff. Control by use of these valves is limited because the moving parts of the valve chatter under certain conditions of pressure and flow. The valve actuator springs will require frequent changing to meet the entire range of operating conditions and this is a difficult operation under field conditions.

A system using the Fisher Type 310 pressure-regulator valves (Fig. 7), Fisher Type 404A back-pressure and relief valves, and a Rockwell Model 503 valve was used as an excess-flow valve. Two important limitations affected the desirability of this configuration. The Fisher Type 310 valve is limited to the amount of pressure drop across the valve. Only 55 percent of the inlet pressure can be dissipated through the valve without experiencing damaging cavitation. The second limitation concerns the allowable

downstream pressure. The Fisher Type 310 valve is constructed to withstand not more than 600 psi.

Figure 8 shows a flow schematic using General Model 5100 valves. A Rockwell Model 503 was used for excess flow. A considerable length of straight pipe is required downstream of the valve to insure a uniform signal to the controlling pilot. This distance could possibly be shortened by the use of straightening veins as shown in the sketch. There was no information on cavitation because of its newness, and preliminary information on flow characteristics revealed some discrepancies.

A configuration of Rockwell Model 503 valves assembled to control all five cases of pipeline operating conditions is shown in Fig. 9. The control schematic for this single pilot mounting is shown in Fig. 10. The standard pressure-control pilot springs are limited in pressure range application. This would require that field personnel select and install pilots containing correct spring ranges. Fifteen separate pilots would be required to cover the pressure range. In addition to the possibility that the wrong pilot would be selected, there exists the probability of logistical support problems associated with multiple loose parts.

A control arrangement with multiple pilot mountings to eliminate the problems associated with loose parts is shown in Fig. 11. Operating personnel would be required to select the correct pilots required for specific operating conditions and place them in operation by opening and closing the correct control-system manifold valve.

A single skid-mounted assembly shown in Fig. 13 uses Fisher Type 404 valves for downstream pressure control, back pressure control, and pressure relief in conjunction with a Rockwell Model 503 valve for excess-flow shutoff. This assembly is approximately twice the cost and weighs 1 ton more than the Rockwell Model 503 control valve and pilot valve assembly shown in Fig. 14. Also, the Fisher Type 404A valve downstream pressure range is limited by cavitation. The pressure drop through the valve should be limited to 80 percent of the inlet pressure to avoid damage.

The assembly as shown in Fig. 14 has the lowest estimated cost and weight and still meets all the requirements set forth in Department of Army Approved Small Development Requirement (SDR) presented as Appendix C of this report.

Investigations of the requirement involved in the preliminary design of the pressure-regulating systems indicated that certain assumptions were necessary. The minimum downstream pressure was assumed to be 150 psi less than the upstream pressure, but not to exceed 1000 lb per square in. gage (psig). For a pressure-reducing system to perform properly while shutting down the line and during periods where the line is shut down, adequate controls are required at all pumps and at the terminal points

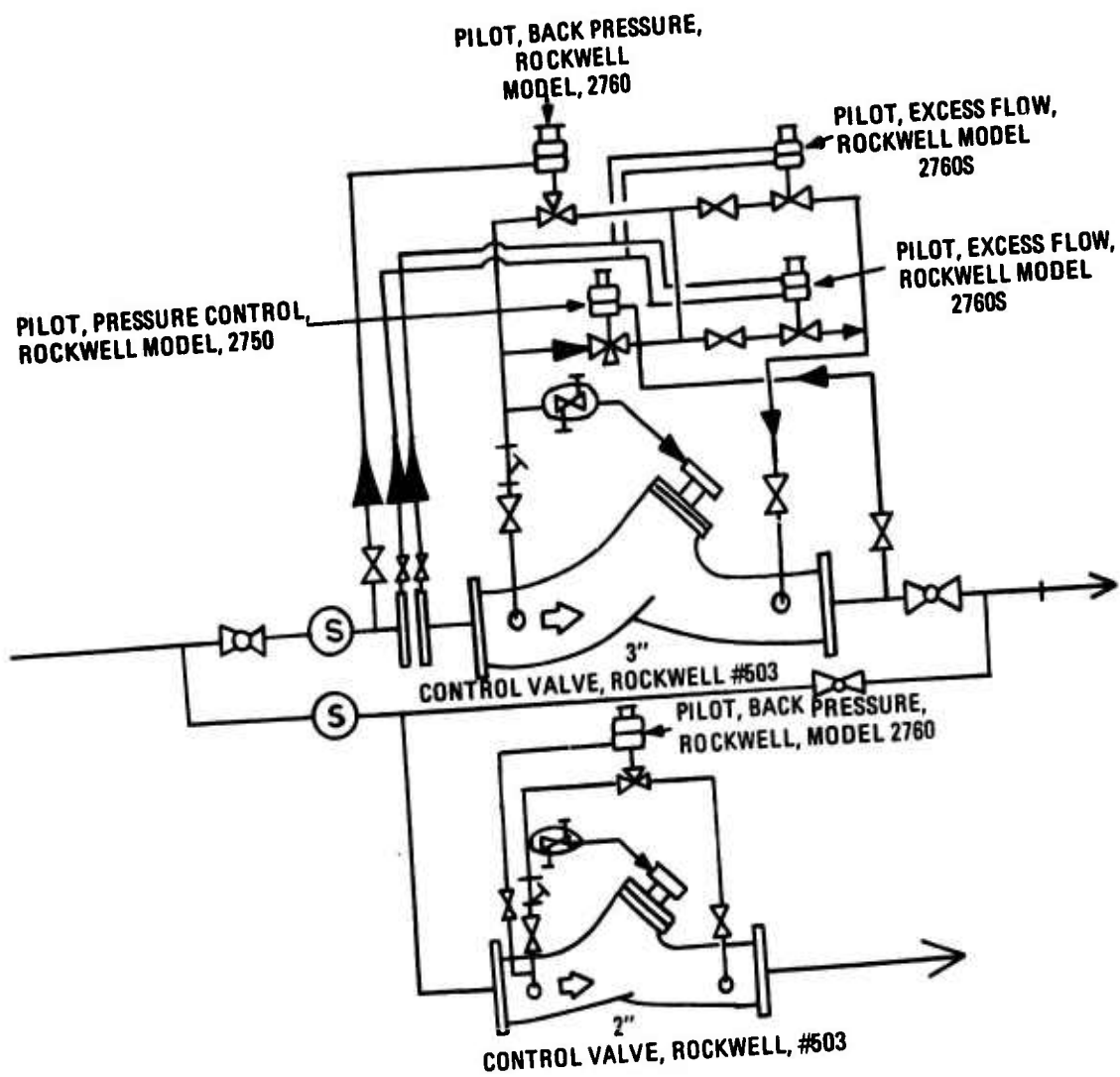


Fig. 14. Rockwell, Model 503, control valves and pilot valve assembly—schematic.

of the pipeline. The assumption was made that pump stations will be equipped with high-discharge, pressure-shutdown controls, and that positive displacement pumps will not be used. A further assumption was that the terminal points of the pipeline will be equipped with flow-rate control and pressure relief upstream of all block valves.

Assumptions were also made in connection with installation of the system. The flexible hose from the relief valve to the collapsible tank will be well anchored. Also, the pressure-regulating system will be well anchored.

The flowing liquid was assumed to be clean.

All investigations were based on the use of standard pipe fittings, except for the extruded headers. All material will be designed for 1440 psig maximum allowable working pressure.

## **6. Design.**

**a. Pressure-Regulating Station.** In 1970, based on the results of Williams Brothers Engineering Company, Resource Sciences Center, Interim Technical Report on Contract DAAK02-70-C-0119, the configuration of Rockwell Model 503 valves, assembled as a single skid-mounted assembly to control all five cases of pipeline operating conditions as shown in Fig. 14, was selected for detailed design. A detailed technical evaluation of the different configurations and concepts was conducted by MERDC.

Work on this contract by Williams Brothers Engineering Company, Resource Sciences Center, was conducted in two phases. The first phase consisted of the compilation of various concepts and configurations of practicable designs; estimates of equipment, manpower, and material needed for each design concept and configuration; tabulation of the advantages and disadvantages of the concepts and configurations together with the necessary computations to determine feasibility; and conclusions and recommendations of method 3, mentioned earlier, which most nearly fulfill the military requirements.

Phase II was dedicated to the final design and selection of materials for the method arrived at in Phase I together with the preparation of military standard, MIL-D-1000, Category E, Form 3 fabrication drawings and specifications. Concurrent with this final design instructions relative to assembly, the makeready for operation, system location for different pipeline conditions, and the operation of the pressure regulating stations covered by the design drawings were prepared. The final technical report was finished in September 1970.

b. **Skid Design.** A skid with permanently affixed lifting attachments was designed to provide support for the assembled regulating station. Sling attachments are arranged so that the assembled station may be handled in the normal operating position. Standard structural steel formulas were used to design the skid. The main skid members were sized with an impact factor of 50 percent and lifting attachments with 150 percent impact factor. Allowances for stresses due to temperature changes from  $-40^{\circ}\text{ F}$  to  $+145^{\circ}\text{ F}$  were made assuming that the unit would be fabricated at approximately  $70^{\circ}\text{ F}$ .

7. **Location.** The elevation difference, pump discharge pressure, friction loss, station inlet pressure, and station outlet pressure must be used to determine a station spacing that will allow full line operation without exceeding the maximum allowable working pressure of the pipe. It is desirable to express these factors in the same units to avoid confusion. The convenient method is to convert all pressures into feet of liquid thus allowing them to be plotted directly on a profile of the pipeline route. This provides a reliable graphic solution for designing a pipeline system. The accuracy of the profile of the pipeline route has a direct effect on the reliability of the design.

A given pressure (in psi) may be converted to equivalent feet of liquid by first multiplying the weight of a column of water 1 square in. in cross section and 1 ft high by the specific gravity of the liquid to be handled. This product is the weight per foot of a column of the liquid to be handled 1 square in. in cross sectional area or pounds per square inch, per foot of column height. By dividing a given pressure by pounds per square inch, per foot of the liquid, the equivalent number of feet of liquid is obtained.

By taking the reciprocal of the number of pounds per square inch, per foot of liquid to be handled, the number of feet of liquid required to produce a pressure of 1 lb per square inch is obtained. This value is very useful in many calculations. Table I gives the approximate values of specific gravity, pounds per square inch, per foot of product, and feet of product required to produce a pressure of 1 lb per square inch for each product specified to be handled.

Table I. Pressure (psi) to Head (ft) Conversion Factors

Product	Specific Gravity	PSI/Ft	Ft/TSI
Aviation gasoline	0.7050	0.3055	3.2733
Motor gasoline	0.7451	0.3229	3.0969
JP-5	0.8450	0.3662	2.7307
Kerosene	0.8200	0.3553	2.8145
Diesel	0.8448	0.3661	2.7315

For determining the correct locations for installing pressure-regulating stations in a pipeline system, it is necessary to have an accurate profile of the pipeline route. The hydraulic gradelines showing the flowing condition and the shutdown condition should be plotted on the profile (see Fig. 15). These plots should be made in feet of liquid. The gradient of the line showing the flowing condition should indicate the friction loss in feet of liquid per unit length of pipeline (usually ft/mi). The grade-line showing the shutdown condition should be horizontal. Pressure-regulating stations must be located so as to maintain a full pipeline and prevent overpressurization of the pipe in both flowing and shutdown conditions.

The allowable pipe pressure limit converted to equivalent feet of liquid, i.e., 600 by 3.09, or 1855 ft, is shown as line B on Fig. 16. If the hydraulic gradeline shutdown condition is found to be above the pipeline profile more than the pipe pressure limit represented by line B, the pipe will be overpressured at that point in the static condition. If the hydraulic gradeline remains above the pipeline profile more than the pipe pressure limit represented by line B, to another point, then that section of line between the two points will be overpressured in the shutdown condition. As shown in Fig. 16 that section of line from point No. 1 downstream would be overpressured during shutdown condition.

To avoid damage to the pipe due to overpressurization of the pipeline section described above, a pressure-regulating station should be installed near the upstream end of the pipeline section. This is described by line A. A hundred feet of head is used as a safety margin and is considered sufficient to allow for any expected variations in the accuracy of the profile.

For shutdown condition, the pressure-regulating station should be adjusted to maintain an upstream pressure approximately equal to the pipe pressure limit. In this example, it is 1,755 ft, or line A.

The downstream pressure to be maintained by the pressure-regulating station must be derived from an examination of the profile of the pipeline downstream of the pressure-regulating station, but cannot be less than 100 psi nor more than 1000 psi.

If the minimum controllable downstream pressure of the pressure-regulating station expressed in equivalent feet of liquid, i.e. 100 psi by 3.1 = 310 ft, is plotted above the profile at the location of the pressure-regulating station, shown as line C, and a horizontal line drawn through this point, shown as line D, extending in the downstream direction, then this horizontal line represents the new hydraulic gradeline for the shutdown condition if the pressure-regulating station is adjusted to maintain the minimum controlled downstream pressure. If this new hydraulic gradeline for the shutdown condition, line D, is found to be above the pipeline profile more than the pipe pressure limit



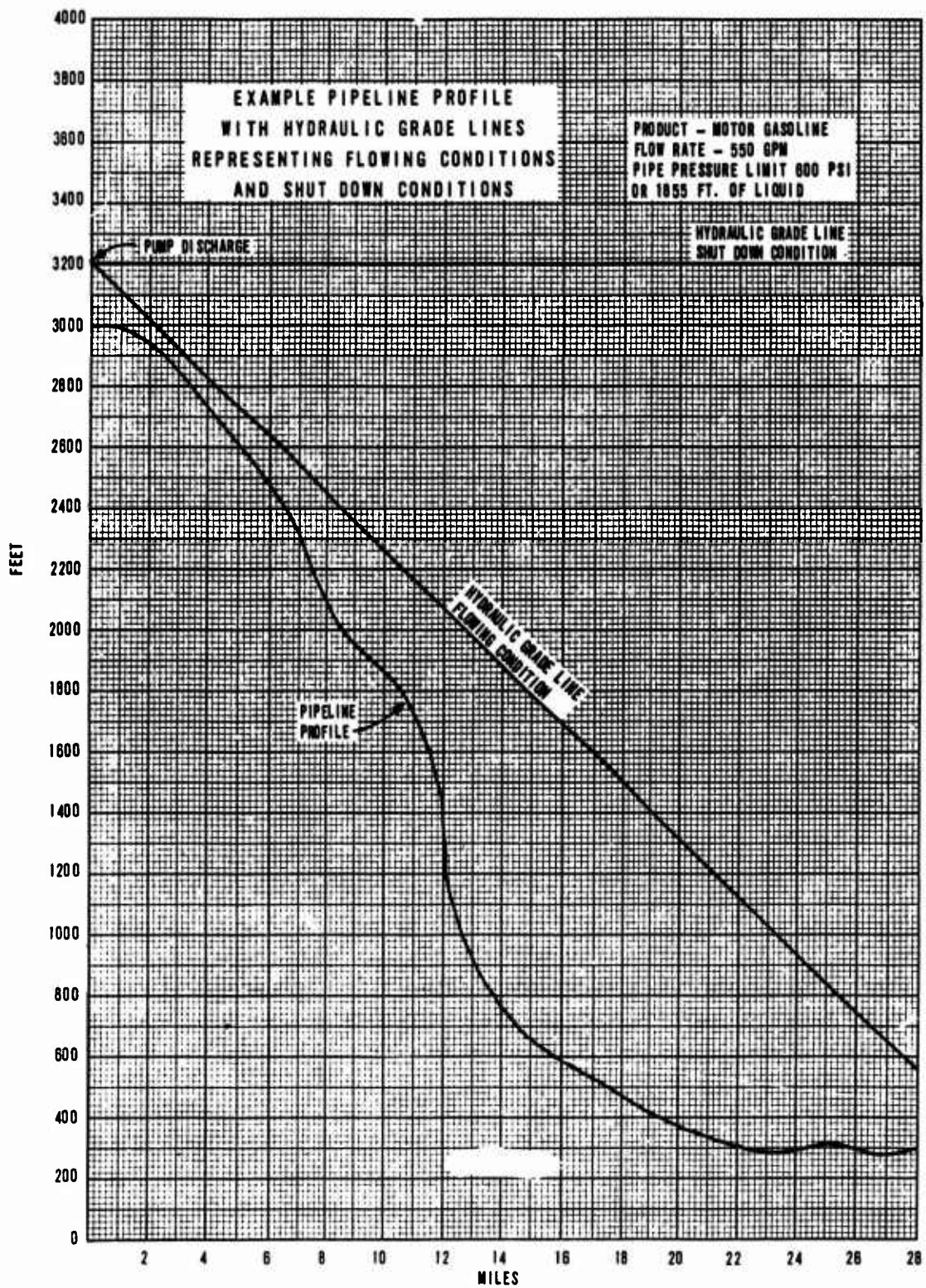


Fig. 15. Example of pipeline profile with hydraulic gradelines representing flowing conditions and shutdown conditions.

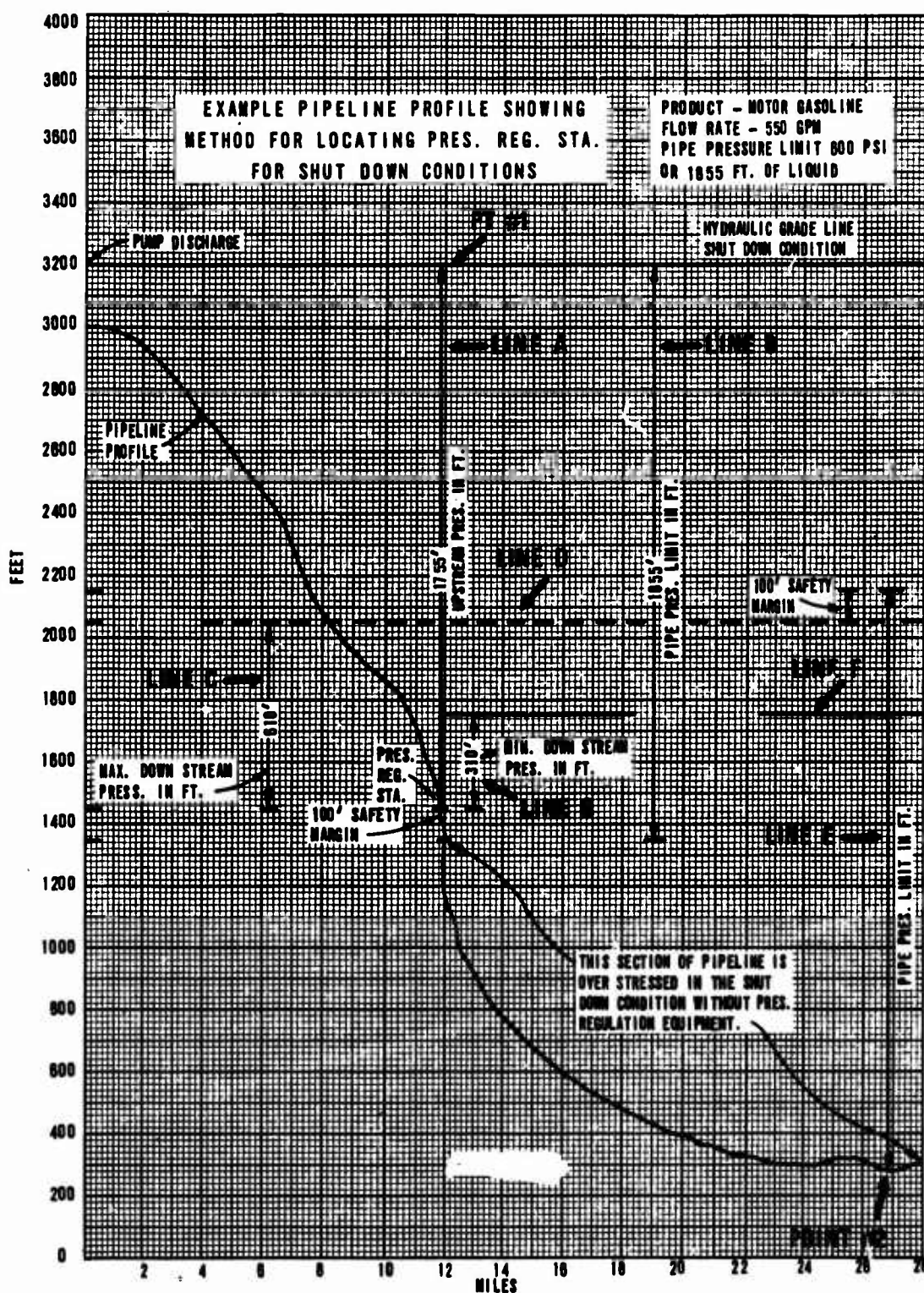


Fig. 16. Example of pipeline profile showing method for locating pressure-regulating station for shutdown conditions.

expressed in equivalent feet of liquid for any point or section, the pipe will be overstressed and another pressure-regulating station must be added in the same manner as previously described.

Where the pipe downstream of a pressure-regulating station is not stressed to the maximum allowable, the controlled downstream pressure may be increased such that the pressure at the low point of the downstream section, point 2, approaches the pipe pressure limit in the shutdown condition. The downstream control setting for this condition is determined by plotting the maximum allowable pipe pressure, expressed in equivalent feet of liquid, vertically above the low point 2 of the downstream section on the profile. This plot is shown as line E, and again 100 ft of head is used as a margin of safety. A horizontal line is drawn through this point, shown in Fig. 16 as line F, to intersect a vertical line drawn upward from the location of the pressure-regulating station. This is represented by line G in Fig. 16. The vertical distance from this intersection to the profile at the pressure-regulating station represents the maximum allowable setting for the controlled downstream pressure expressed in equivalent feet of liquid. As shown in line G, this amounts to 610 feet or 195 psi. If the minimum controllable downstream pressure of the pressure-regulating station expressed in equivalent feet of liquid is plotted above the profile at the location of the pressure-regulating station, and a horizontal line is drawn through this point extending in the downstream direction, then this horizontal line represents the new hydraulic gradeline for the shutdown condition if the pressure-regulating station is adjusted to maintain the minimum controlled downstream pressure. If this new hydraulic gradeline for the shutdown condition is found to be above the pipeline profile more than the pipe pressure limit expressed in equivalent feet of liquid for any point or section, the pipe will be overstressed and another pressure-regulating station must be added in the same manner as previously described. If the new hydraulic gradeline is not above the pipeline profile at any point more than the pipe pressure limit expressed in equivalent feet of liquid, the pipe will not be overstressed in the shutdown condition. In cases where the pipe downstream of a pressure-regulating station is not stressed to the maximum allowable, the controlled downstream pressure may be increased such that the pressure at the low point of the downstream section approaches the pipe pressure limit in the shutdown condition. The downstream pressure-control setting for this condition can be determined by plotting the maximum allowable pipe pressure, expressed in equivalent feet of liquid, vertically above the low point of the downstream section on the profile, then drawing a horizontal line through this point to intersect a vertical line drawn upward from the location of the pressure-regulating station. The vertical distance from this intersection to the profile at the pressure-regulating station represents the maximum allowable setting for the controlled downstream pressure expressed in equivalent feet of liquid. This setting should be adjusted to allow a sufficient margin of safety to provide for any expected variations.

After finalizing the location of the pressure-regulating stations for the shutdown condition, these locations should be checked to determine if they are practicable for the flowing condition. The procedure for checking the locations of the pressure-regulating station in the flowing condition is similar to the procedure used to locate the stations for the shutdown condition. The maximum allowable pipe pressure expressed in equivalent feet of liquid must be compared to the difference in elevation of the profile of the pipeline route and the hydraulic gradeline for the flowing condition.

As previously stated, the hydraulic gradeline for the flowing condition should be plotted on the profile used for locating stations for shutdown conditions. After pressure-regulating stations have been located and downstream pressures set for the shutdown condition, the hydraulic gradeline for the flowing condition must be corrected for the new set of conditions which have been created (see Fig. 17). At each pressure-regulating station the downstream pressure expressed in equivalent feet of liquid should be plotted above the pipeline profile and a line drawn through the point parallel to the hydraulic gradeline for the flowing condition. These new lines represent the hydraulic gradeline for the flowing condition reflecting the effect of the pressure-regulating stations and should be used as the basis for further analysis. The hydraulic gradeline for the entire pipeline under flowing conditions should now be checked to determine if it exceeds the pipe pressure limit expressed in equivalent feet of liquid at any point or for any section. If it does exceed the pipe pressure limit at any point or for any section, that point or section will be overpressured during flowing conditions. To prevent damage to the pipe, a pressure-regulating station should be installed upstream of the point at which the pipe will first become overpressured. The station should be installed a sufficient distance upstream of the point at which the pipe becomes overpressured to allow for any variations expected in the accuracy of the pipeline profile. The downstream pressure of the station should be set as high as possible without overstressing the pipeline in the downstream section. The new hydraulic gradeline showing the effect of the pressure-regulating station may be drawn by plotting the station discharge pressure in equivalent feet of liquid above the pipeline profile at the location of the pressure-regulating station and drawing a line through that point with a gradient equal to the friction loss in equivalent feet of liquid per unit length of pipeline for the flowing condition.

When designing a new pipeline, pump stations can be located as needed according to the hydraulic gradeline showing the effect of pressure-regulating stations. Where an existing pipeline that has been operated as an open or slack line on downhill sections is to be equipped with pressure-regulating systems and operated at full capacity, existing pumping equipment may have to be relocated.



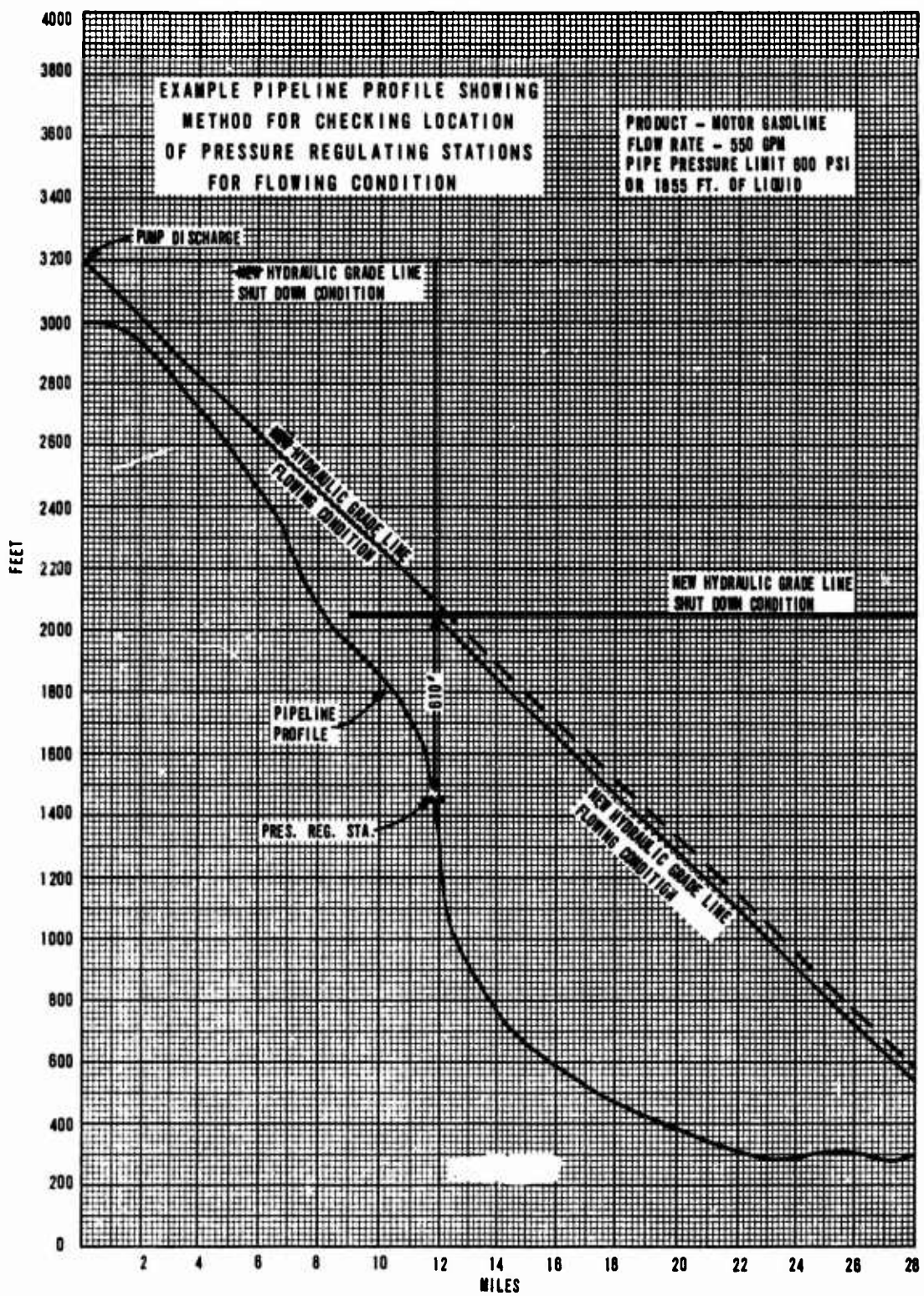


Fig. 17. Example of pipeline profile showing method for checking location of pressure-regulating stations for flowing conditions.

**8. Installation.** After determining the theoretical location for a pressure-regulating station there are factors that can be considered to enhance the operational ease. Care must be exercised to ascertain that while these factors make a station site more operationally convenient, they should not be exercised to the extent that hydraulic parameters are violated.

When possible, a level site with a fairly smooth surface and soil having good bearing strength should be selected. This provides a better work area and allows for simpler construction of foundations if they are to be utilized. Although the pressure-regulating station does not require constant attendance, it is desirable to have the station accessible by ground vehicles so that it can be easily and quickly reached for periodic maintenance and adjustments; therefore, a site near a road should be selected when possible. Occasionally communication between the pressure-regulating station and other facilities on the pipeline may be advantageous, so an attempt should be made to avoid locating the station in a radio "dead spot." These suggestions for site selection have no effect on the operation of the pressure-regulating station but are recommended for consideration in reducing the effort involved in installing and operating a pressure-regulating station over a long period of time.

Concrete foundations with anchor bolts are preferred for the pressure-regulating station. These foundations should be constructed so that the pressure-regulating station skid will be level when installed on the foundations. Level foundations are advantageous in reducing wear on the anchor bolts caused by equipment vibration, but have no effect on the operation of the equipment. If the foundation is capped with a smooth slab, 1 in. of grout should be provided around the anchor bolts as indicated on Drawing No. DAAK02-70-C-0119-WBEC-5, "Piping Skid and Fabrication Details," in Appendix B of this report. The grout is intended to provide clearance under the skid for water drainage.

When installing a pressure-regulating station, care must be taken to insure that the station is installed so that the station inlet is connected to the upstream pipeline section and the outlet is connected to the downstream pipeline section. This arrangement is necessary because the Rockwell Model 503 control valve is not designed for bidirectional flow. If the pressure-regulating station is inadvertently installed backwards in the pipeline, the control valve will close and remain closed. Adjustment of the pilots will not correct this condition. The control equipment will not be damaged by reverse flow as described above; however, it will not function properly until the station is correctly installed so that the flow through the station is in the proper direction. The correct flow direction is indicated by arrows on the piping plan drawing in Appendix B of this report.

All piping to the pressure-regulating station should be anchored if it is above ground for more than 10 ft on either side of the station. Where piping between the pressure-regulating station and other facilities, such as scraper traps, is above ground, the pipe should be anchored. Underground piping should be provided with a support under bends or fittings used to bring the pipe above ground for connection to a pressure-regulating station.

When scraper traps are installed in conjunction with a pressure-regulating station, the 2-in. safety relief valve and the 2-in. basket strainer should be removed from the pressure-regulating station and installed upstream of the upstream scraper trap and associated valves (see Figs. 1 and 18). The blind flange should be removed from the downstream flange of the 2-in. safety relief valve and installed on the 2-in. flange from which the 2-in. safety relief valve was removed.

When scraper traps are not used in conjunction with a pressure-regulating station, the 2-in. safety relief valve may remain in the system as shown on the piping plan and sections drawing in Appendix B of this report. The blind flange must be removed from the downstream flange of the 2-in. safety relief valve before starting operations.

In either of these two arrangements, the downstream flange of the 2-in. safety relief valve is to be connected to a flexible hose from a collapsible tank. The flexible hose should be securely anchored to prevent excessive movement of the hose caused by flowing product.

**9. Startup and Adjustment.** When the pipeline is initially started up, each pressure-regulating station must be operated manually until the pipeline is completely flushed out and the controls are properly adjusted. While the pipeline system is being flushed out, the 4-in. bypass line must be used and the 4-in. gear-operated ball valve must be used to control the upstream and downstream pressure. The 6-in. and 3-in. ball valves should be completely closed while the pipeline is flushed out. These ball valves are shown on piping schematic, Fig. 1. This is done to prevent an accumulation of foreign material in the control system strainers. Pressure gages should be installed at the inlet and outlet of the station.

Some problems associated with startup can be avoided by installing a large mesh strainer upstream of the pressure-regulating station. A 10- or 20-mesh strainer will collect any particles or objects large enough to block the pipe or the ball valve. The large mesh will allow fine particles to pass through, thus permitting the strainer to remain in service a longer period of time without cleaning. If it is desired to remove the fine particles, a finer mesh can be installed; however, it should be understood that numerous strainer cleanings may be required on initial startup, resulting in delays in

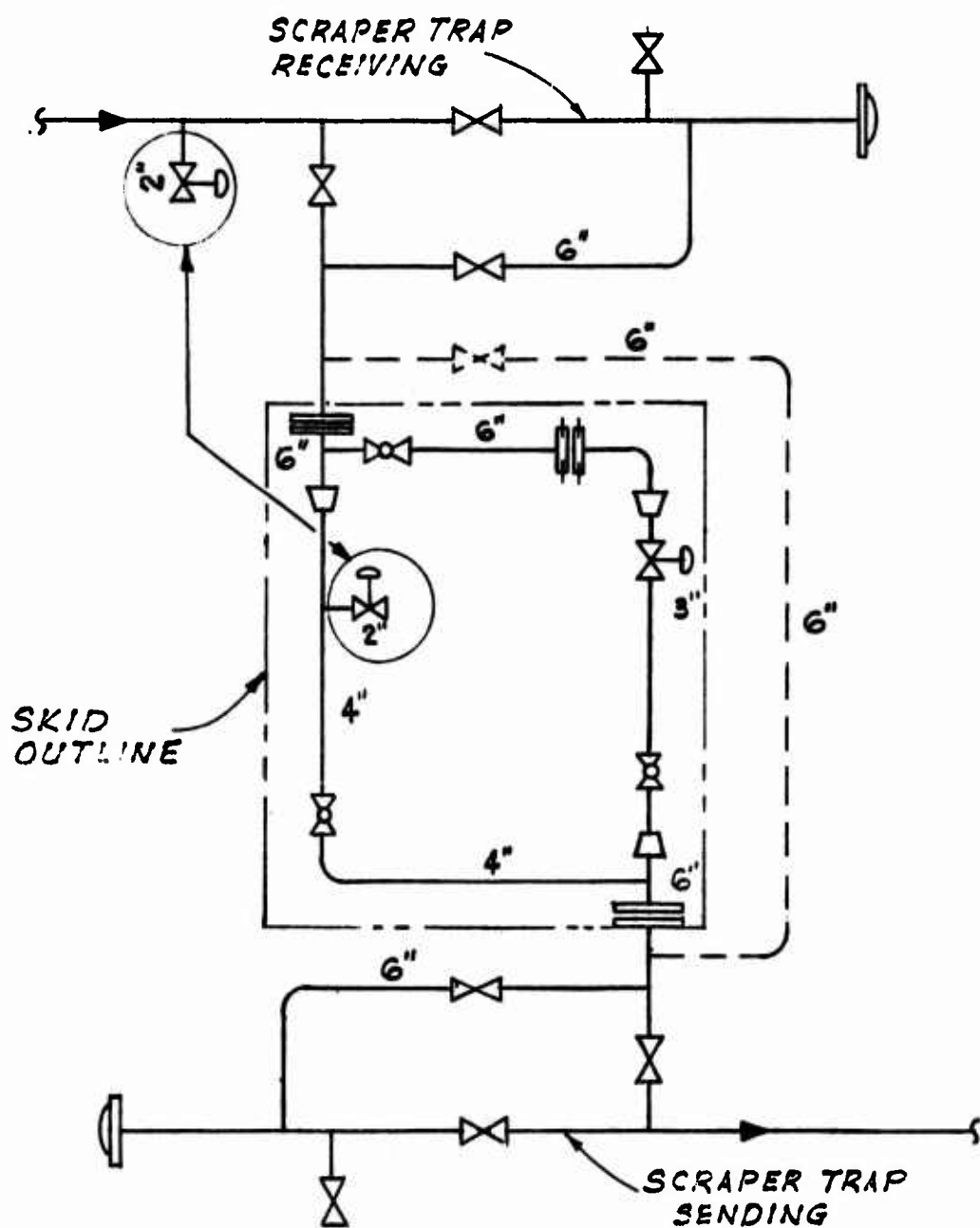


Fig. 18. Relief valve installation.



product delivery. Delays in product delivery are considered highly undesirable; therefore, the large mesh strainer is recommended.

Once the pipeline has been flushed out and clean product is flowing through the station, the 3-in. Rockwell Model 503 control valve can be adjusted and put into operation. The control valve pilots are equipped with position indicators to aid in adjustment. Properly calibrated position indicators will provide a means for approximate adjustment without flowing product through the control valve.

A calibration test for each portable pressure-regulating station should be required before it is sent to the field for installation in a pipeline. This calibration test will provide data from which calibration charts may be compiled. Calibration charts will provide a correlation between the pilot indicator settings and the control-valve operation. Calibration charts should be shipped with each pressure-regulating station and included in each operating manual. The adjustment procedure given in this discussion is extended to cover situations where the calibration charts are not available to the operating personnel during the initial startup. It should be understood that startups and adjustments without calibration charts introduce additional possibilities for overpressurization of the pipe since it requires manual operation of the valves to control pressures very near the pipe pressure limit. This procedure of adjustment also requires additional time, more adjustments, and more technical ability on the part of the operating personnel than does the calibration chart procedure. Startups and adjustments by use of calibration charts are less complicated and should be employed as normal procedure.

The pilots should be adjusted to the desired setting accordingly. These settings will be close approximations; however, some additional adjustment under flowing conditions may be necessary. If calibration charts are not available, the pilots must be set to a positive opened or a positive closed setting depending on their function, and adjusted to the desired setting under flowing conditions. The back-pressure pilot on the safety relief valve and the high-pressure relief pilot on the control valve should be adjusted to the positive closed setting and the reducing-pressure control pilot should be adjusted to the positive opened setting. The above adjustments should be made prior to starting flow through the control valve.

The following is a suggested startup and adjustment procedure for a pressure-regulating station:

Install pressure gages at the inlet and the outlet of the station, and close the 6-in. and 3-in. ball valves.

Flush pipeline through 4-in. bypass line. Manually operate the 4-in. ball valve to control the upstream and downstream pressures while flushing the pipeline. This is done by partially closing the valve to obtain the desired downstream pressure. Do not close the valve completely. Caution must be exercised to prevent exceeding the safe upstream and downstream operating pressures.

Make initial pilot adjustments.

Adjust the high-pressure relief pilot to the desired setting as shown on the calibration chart. If no calibration chart is available, adjust the high-pressure relief pilot to a positive closed setting.

Adjust the reducing-pressure control pilot to the desired setting as shown on the calibration chart. If no calibration chart is available, adjust the reducing-pressure control pilot to a positive opened setting.

The excess-flow pilots are preset and should not require adjustment.

Adjust the back-pressure pilot on the 2-in. safety relief valve to the desired setting as shown on the calibration chart. If no calibration chart is available, adjust the pilot to a positive closed setting.

Open valves indicated as R1, R2, R3, and PNR on Fig. 19.

Make final adjustment on 2-in. safety relief valve:

Increase the upstream pressure by adjusting the 4-in. ball valve closure until the pressure gage at the station inlet indicates the upstream pressure is equal to the pressure setting required for the safety relief valve. This setting can be obtained from Table II. Do not close the 4-in. ball valve completely.

Adjust the safety relief valve pilot so that the safety valve starts to open.

Decrease the upstream pressure by adjusting the 4-in. ball valve closure until the safety relief valve closes. Care should be taken not to exceed the safe downstream pressure.

Increase the upstream pressure by adjusting the 4-in. ball valve closure. Note the upstream pressure at which the safety relief valve starts to open. If the valve starts to open before the upstream pressure has increased to within 10 psi of the required setting, the pilot should be adjusted so that it will not open until the upstream pressure increases to within 10 psi of the required setting. If the valve does not open

Table II. Specified Operating Conditions

Case No.	Pipe Size and Type	Type of Line Construction	Normal <sup>4</sup> Flow (gpm)	Emergency <sup>5</sup> Flow (gpm)	Pipe <sup>6</sup> Pressure Limit (psig)	Set Point for Valve to Relieve to Downstream Section (psig)	Set Point for Valve to Relieve to Collapsible Tank (psig)
1	6" Tubing <sup>1</sup>	Grooved and <sup>2</sup> Coupled	550	700	600	660	700
2	8" Tubing <sup>1</sup>	Grooved and <sup>2</sup> Coupled	950	1210	500	550	600
* 3	12" Tubing <sup>1</sup>	Grooved and <sup>2</sup> Coupled	5000	7970	400	440	500
4	8" Pipe <sup>3</sup>	Welded	1100	N/A	1340	1390	1440
5	12" Pipe <sup>3</sup>	Welded	2600	N/A	1140	1190	1240

<sup>1</sup>MIL-T-425 - Tube, steel: Pipeline section; with grooved nipple welded on each end.

<sup>2</sup>MIL-C-10387 - Coupling, clamp, pipe; with bolts and synthetic rubber gasket for grooved end pipe and tube.

<sup>3</sup>MIL-P-11067 - Pipe, steel: Grooved, threaded, or plain end.

<sup>4</sup>Normal flow, in gallons per minute, is the normal military design capacity for the particular line size and type of construction. Pipeline design flow rate is based on gasoline of 0.725 specific gravity and kinematic viscosity of 0.62 centistokes at 60° F.

<sup>5</sup>Emergency flow, in gallons per minute, is a maximum operable condition which may be attained in a military pipeline for relatively short operating periods. This flow is also based on gasoline at 60° F. The design of the regulating systems, to the extent feasible and efficient, will result in minimum pressure losses through the regulating systems at the emergency flows listed.

<sup>6</sup>Pipe pressure limits are the allowable pipeline pressures at the inlet to the upstream side of the pressure-regulating systems. The pressures specified indicate the maximum spacing between pressure-regulating stations or locations of the pressure-regulating systems in a military pipeline, as a result of considering the dynamic flow and static conditions of the pipeline plus the minimum specified downstream pressure.

\* Deleted by Contract Amendment Modification No. P001.

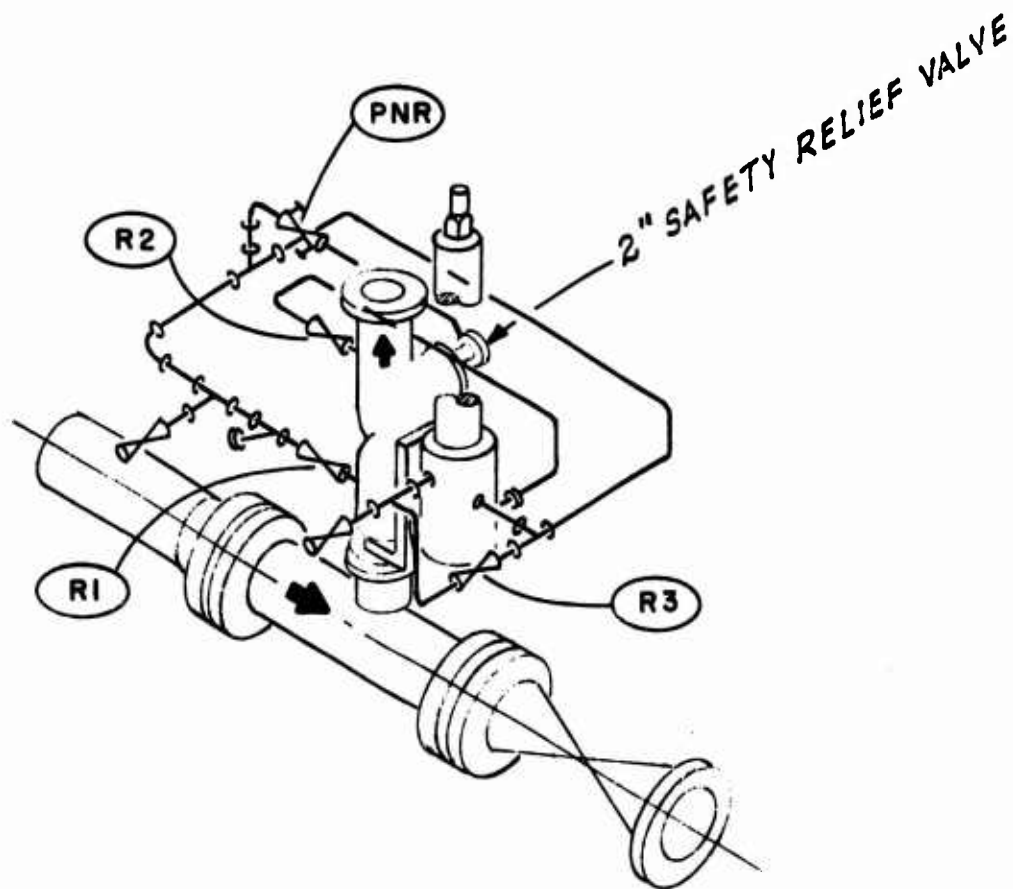


Fig. 19. Relief valve pilot schematic.

when the pressure reaches the required setting, the pilot must be adjusted so that it will open at the required pressures. If the safety valve starts to open at the required pressure setting, or not more than 10 psi under the required pressure setting, the pilot adjustment is satisfactory. Under no circumstance should the upstream pressure be allowed to increase above the required setting for the safety relief valve. Higher pressures could result in damage to the pipe and other equipment.

Repeat the above adjustment until a satisfactory pilot setting is obtained. Then adjust the 4-in. ball valve to maintain an upstream pressure slightly less than the pressure at which the safety relief valve opens.

Open valves indicated as C1, C2, C3, PNC, E1, E2, E3, E4, and B1 on Fig. 20.

Make final adjustment on reducing-pressure control pilot. (At this point, the 4-in. manually operated ball valve is still controlling both upstream and downstream pressures and all flow is through the 4-in. bypass line.)

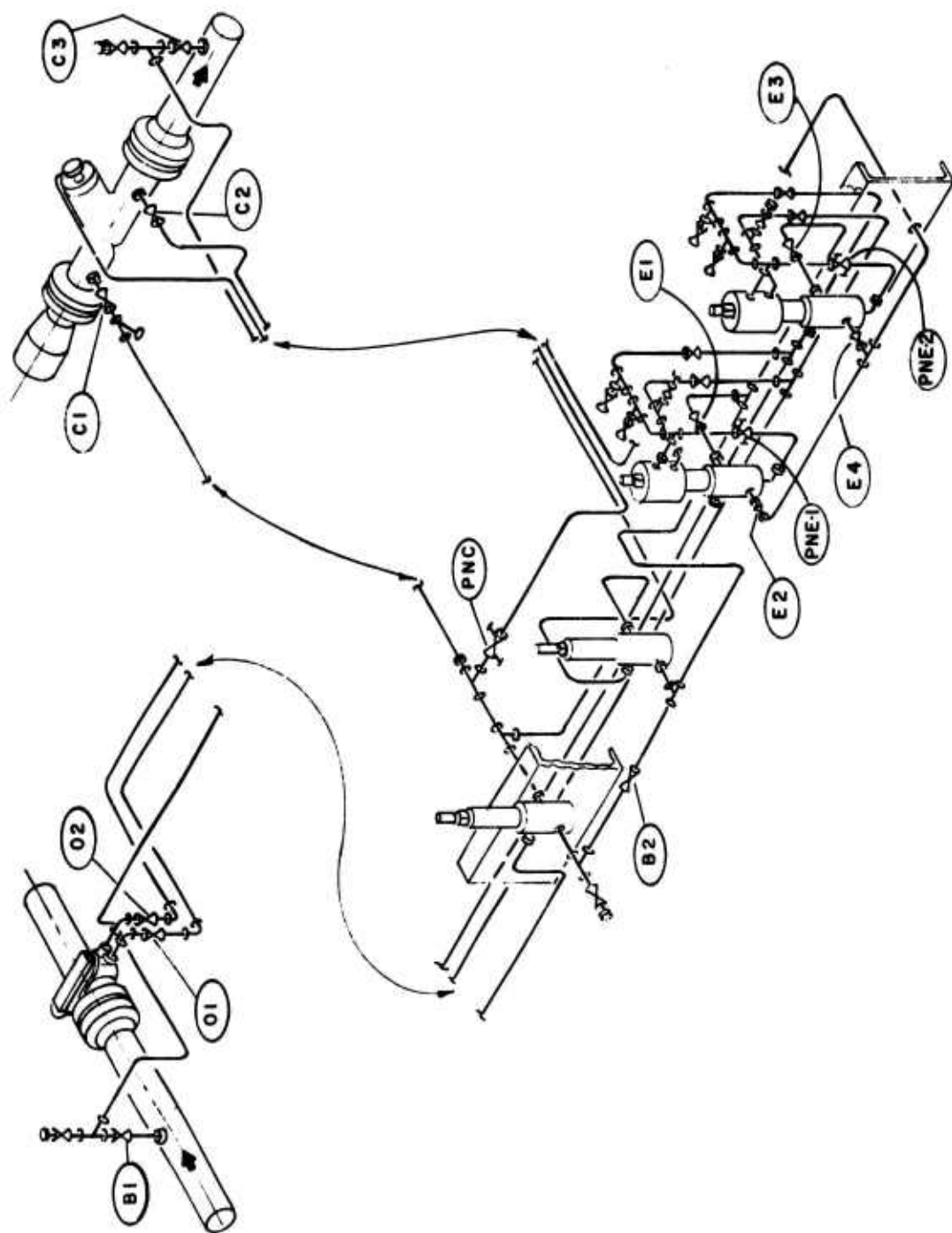


Fig. 20. Control valve pilot schematic.

Install an upstream pressure gage on the high-pressure relief pilot signal line and a downstream pressure gage on the reducing-pressure control pilot signal line.

Open the 6-in. ball valve and allow liquid to flow into the 3-in. control valve, and observe the pressure downstream of the control valve as indicated by the pressure gage on the reducing-pressure control pilot signal line. If this pressure does not increase at least to the desired downstream pressure, adjust the reducing-pressure control pilot so that this pressure is equal to or greater than the desired pressure.

Manually adjust the closure of the 4-in. ball valve so that the downstream pressure, as indicated by the gage at the outlet of the station, is less than the maximum safe downstream operating pressure and the upstream pressure is less than the pressure at which the safety relief valve starts to open. When possible, the downstream pressure should be at least 50 psi less than the maximum safe downstream operating pressure.

Manually adjust the closure of the 3-in. ball valve so that the downstream pressure as indicated by the pressure gage at the outlet of the station is equal to the maximum safe downstream operating pressure. (At this point the stream is split. Part of the flow is through the 4-in. bypass and part of the flow is through the 3-in. control valve.)

Adjust the reducing-pressure control pilot so that the downstream pressure as indicated by the pressure gage on the reducing-pressure control pilot signal line is equal to the desired downstream pressure. The high-pressure relief pilot must be closed before the control valve will respond to adjustment to the reducing-pressure control pilot.

Manually adjust the closure of the 3-in. ball valve so that the downstream pressure as indicated by the pressure gage on the station outlet decreases. Observe the downstream pressure as indicated by the gage on the reducing-pressure control pilot signal line. If it remains constant at the desired downstream pressure setting, or returns to this setting after a brief period for stabilization, then the reducing-pressure control pilot is properly adjusted.

Close the 3-in. ball valve. The upstream pressure as indicated by the pressure gage on the inlet of the station should be slightly less than the pressure at which the safety relief valve starts to open; the downstream pressure as indicated by the pressure gage on the outlet of the station should be less than the maximum safe downstream operating pressure; and the downstream pressure as indicated by the pressure gage on the reducing-pressure control pilot signal line should be approximately equal to the desired downstream pressure.

**Open valve indicated as B2 on Fig. 20.**

**Make final adjustment on high-pressure relief pilot.**

**Manually adjust the closure of the 4-in. ball valve so that the upstream pressure as indicated by the pressure gage on the inlet of the station is equal to the desired high-pressure relief pilot setting. This setting can be obtained from Table II.**

**Adjust the high-pressure relief pilot so that the 3-in. control valve starts to open. At this point the pressure as indicated by the gage on the reducing-pressure control pilot signal line may start to increase.**

**Close the 6-in. ball valve.**

**Open the 3-in. ball valve to relieve the pressure in the 3-in. control valve. When the pressure as indicated by the gage on the high-pressure relief pilot signal line and the pressure indicated by the gage on the reducing-pressure control pilot line are approximately the same as the pressure indicated by the gage on the station outlet, close the 3-in. ball valve.**

**Manually adjust the closure of the 4-in. ball valve so that the upstream pressure as indicated by the pressure gage on the inlet of the station is less than the desired high-pressure relief pilot setting and the downstream pressure as indicated by the pressure gage on the outlet of the station is not in excess of the maximum safe downstream operating pressure.**

**Adjust the closure of the 6-in. ball valve such that 2 to 3 minutes are required for the gage pressure as indicated by the pressure gage on the high-pressure relief pilot signal line to become approximately equal to the upstream pressure as indicated by the pressure gage on the station inlet. At this point, the downstream pressure as indicated by the pressure gage on the reducing-pressure control pilot signal line should be approximately equal to the desired downstream pressure setting. The 6-in. ball valve can be adjusted to the full open position.**

**Increase the upstream pressure by adjusting the closure of the 4-in. ball valve. Note the upstream pressure as indicated by the pressure gage on the high-pressure relief pilot signal line at which the 3-in. control valve starts to open. If the valve starts to open before the upstream pressure has increased to within 10 psi of the desired setting, the high-pressure relief pilot should be adjusted so that it will not open until the upstream pressure increases to within 10 psi of the desired setting. If the valve does not open when the pressure reaches the desired setting, the high-pressure relief pilot must be adjusted so that the valve will open at the desired pressure. If the 3-in. control valve**

starts to open at the desired pressure setting or not more than 10 psi under the desired pressure setting, the high-pressure relief pilot adjustment is satisfactory. During the above adjustment, complete closure of the 4-in. ball valve should be avoided, and pressures high enough to open the safety relief valve should not be reached.

Repeat the above adjustment until a satisfactory high-pressure relief pilot setting is obtained.

Check out excess-flow pilot setting. (At this point, the 4-in. manually operated ball valve is still controlling both upstream and downstream pressure and all flow is through the 4-in. bypass line. The 6-in. ball valve is open and the 3-in. ball valve is closed.)

Determine which excess-flow pilot is to be used. The excess-flow pilot shown in Detail "A" of Drawing No. DAAK02-70-C-0119-WBEC-3 (Appendix B) should be used for operations where the flow rate is planned to be in excess of 1300 gpm, and the excess-flow pilot shown in Detail "B" of Drawing No. DAAK02-70-C-0119-WBEC-3 should be used for flow rates less than 1300 gpm.

Close the valves to the inlet stream and the outlet stream of the excess-flow pilot that is not to be used. Also close the valves to the orifice lines of this pilot.

Open the valves to the inlet stream and the outlet stream of the excess-flow pilot that is to be used. Also open the valves to the orifice lines of this pilot. Open the valves to the orifice lines at the orifice, indicated as 01 and 02 on Fig. 20. Bleed all air from the orifice lines.

Remove the pressure gage from the high-pressure relief pilot signal line and the pressure gage from the reducing-pressure control pilot signal line. Install one pressure gage on the high-pressure orifice line of the pilot that is to be used and one pressure gage on the low-pressure orifice line of the pilot that is to be used. The indicated pressures on these two gages should be the same.

Close valve 02 in the low-pressure orifice line upstream of the pressure gage and note the pressure indicated by this pressure gage.

Increase the upstream pressure by adjusting the closure of the 4-in. ball valve. Increase the upstream pressure until the excess-flow pilot starts to close. Note the pressure indicated by the pressure gage on the high-pressure orifice line and the pressure indicated by the pressure gage on the low-pressure orifice line at the time the excess-flow pilot starts to close. The difference in these two pressures should be



approximately 17.1 psi for the pilot to be used for flow rates not to exceed 1300 gpm, or 90.0 psi for the pilot to be used for flow rates exceeding 1300 gpm.

An alternate method to that described would be to close valve 02 in the low-pressure orifice line upstream of the pressure gage, close valve 01 in the high-pressure orifice line upstream of the pressure gage, and open the drain valve on the low-pressure orifice lines near the gage, thus allowing pressure to bleed off to obtain a differential pressure across the pilot. The setting can be checked by noting the differential pressure at which the pilot starts to close. This alternate method should be used if the pilot cannot be checked as described in the paragraph above.

If the pilot fails to close at the proper setting, repeat the procedure on the other excess-flow pilot. If this pilot closes at the required differential pressure for the existing conditions, it should be used. No adjustment to the excess-flow pilots should be attempted under field operating conditions unless absolutely necessary, and then only if very accurate, calibrated, test pressure gages are available. If it is determined that an excess-flow pilot should be adjusted, when possible, it should be removed from the regulating station and taken to a shop where delicate pressure gages can be used.

Adjust Pneu-Trol valve. At this point, the 4-in. manually operated ball valve is still controlling both upstream and downstream pressure and all flow is through the 4-in. bypass line. The 6-in. ball valve is fully open and the 3-in. ball valve is closed.

Close the inlet valve C3 (Fig. 20) to the signal line of the reducing-pressure control pilot and bleed the pressure from this signal line. This will allow the 3-in. control valve to open to a fully open position.

Decrease the downstream pressure by manually adjusting the closure of the 4-in. ball valve. This adjustment should produce an upstream pressure slightly less than the pressure required to open the safety relief valve.

Increase the downstream pressure to the safe working pressure by manually adjusting the closure of the 3-in. ball valve. Do not exceed the maximum allowable downstream pressure.

Close both orifice line valves 01 and 02 (Fig. 20) at the orifice, and open the Pneu-Trol valves indicated as PNE-1 and PNE-2 (Fig. 20).

Bleed pressure from the low-pressure orifice line of the excess-flow pilot being used until the excess-flow pilot starts to close.

Observe the time interval required for the 3-in. control valve to completely close, and adjust the Pneu-Trol valve indicated as PNC on Fig. 20 so that this time interval is approximately 7 or 8 seconds.

Open valves 01 and 02 and manually reset the excess-flow pilot.

Repeat the procedure until a time interval of approximately 7 or 8 seconds for valve closure is obtained.

Use the same procedure for setting the Pneu-Trol valve, PNE-1 or PNE-2, on the excess-flow pilot being used. This Pneu-Trol valve should be adjusted after Pneu-Trol valve PNC is adjusted and should slow the closure of the 3-in. control valve to approximately 30 seconds.

Open the inlet valve C3 to the signal line of the reducing pressure control pilot, and open valves 01 and 02. Close the 3-in. ball valve.

Switch from manual operation to hydraulic operation. (At this point, the 4-in. manually operated ball valve is still controlling both upstream and downstream pressure and all flow is through the 4-in. bypass line. The 6-in. ball valve is fully open and the 3-in. ball valve is closed.)

Check the valves on the inlet pilot lines, the outlet pilot lines, and the pilot signal lines to assure that all are open except those to the one excess flow that is not to be used. The valves to the inlet pilot line, the outlet pilot line, and the orifice lines should be closed to the excess-flow pilot that is not to be used.

Decrease the downstream pressure by manually adjusting the closure of the 4-in. ball valve. This adjustment should produce an upstream pressure slightly less than the pressure required to open the safety relief valve.

Increase the downstream pressure to the desired setting by manually adjusting the closure of the 3-in. ball valve. Do not exceed the maximum allowable downstream pressure.

Again increase the upstream pressure by adjusting the closure of the 4-in. ball valve. If the upstream pressure closely approaches the pressure required to open the safety relief valve before the 4-in. ball valve is completely closed, adjust the closure of the 3-in. ball valve to increase the downstream pressure to the desired setting. Repeat this operation until the 4-in. ball valve is completely closed and the 3-in. ball valve is fully open. The 3-in. control valve will control the pressures if previous adjustments have been done correctly.

**10. Operation.** Once the pressure-regulating system has been installed, adjusted, and put into service, it will not require operating personnel on a continuous basis. The system will operate unattended and without an external power source. The equipment will operate solely on pipeline hydraulic pressure and will be self-regulated. The pressure-regulating system will function during conditions as follows:

- a. Pipeline system startup.
- b. Pipeline system shutdown.
- c. Normal flow.
- d. Emergency flow.
- e. Excess flow (line break).
- f. Shutdown (static).

The portable pressure-regulating system will control military petroleum fuels as follows:

- a. Aviation gasoline—grades 80/87, 100/130, 115/145.
- b. Motor gasoline—regular and premium.
- c. JP-4.
- d. Kerosene.
- e. Diesel—grades DF-A, DF-1, DF-2.

The pressure-regulating system will operate to prevent overpressurization of the pipeline and maintain a packed multiproduct pipeline during operation or shutdown conditions. The pressure-regulating system will function to prevent overpressurization of the pipeline due to pressure surges which may be caused by opening and closing block valves, starting and stopping pumps, and fuel expansion in a closed line. The pressure-regulating system will function to maintain the minimum downstream pressure irrespective of flow rate or upstream pressure during either pipeline operating or shutdown conditions except when the upstream pressure increases to the pressure at which it is relieved into the downstream section. The portable pressure-regulating system, when properly adjusted, will operate to prevent upstream pressures from exceeding the limits listed in Table II. This operation is primary protection for each upstream pipeline section during

shutdown conditions and will pass product from the upstream pipeline section to the downstream pipeline section. The portable pressure-regulating system will provide operation to shut down pipeline flow in the event of a downstream line break. Close-off rate of pipeline flow will be such as to contain pressure surges within acceptable limits. The pressure-regulating equipment operating under these emergency shutdown conditions is provided with manual reset capability. The safety relief valve will prevent pipeline overpressurization due to human error or other circumstances whereby block valves are closed. Also, the safety relief valve will protect the pipeline from pressure surges encountered during normal and emergency operating conditions. The safety relief valve will function to prevent pipeline overpressurization due to fluid expansion in a closed system.

Pipeline shutdown should be accomplished by shutting down the pump stations and closing the block valve at the terminal end, the line will then drain and become slack. When pump stations are equipped with high-discharge pressure switches that will shut down the pumps, the block valve at the terminal end of the pipeline can be closed off and the pumps will shut off as the discharge pressure increases. The latter method of shutting down the line may be used where no communication between the terminal end of the pipeline and the pump stations exists and should be employed only when necessary. This type of shutdown is the same type that results from excess flow due to line break, and can produce problems if the pump stations do not shut down. If, for example, the pumps only throttle back and do not shut down, the pump will probably continue to put up a discharge pressure sufficient to open the high-pressure relief pilot and the safety relief valve. In this situation, the pressure-regulating station has performed properly by first closing off because of high downstream pressure. If the pump stations continue to pump, the upstream pressure will approach the pipe pressure limit and the high-pressure relief pilot will open the 3-in. control valve, thus increasing the downstream pressure. At this point, one of two sequences is likely to occur, depending on what initiated the shutdown:

a. If the shutdown occurs as the result of a downstream pressure-regulating station closing off the stream (because of excess flow or some other reason) the pressure will increase in the downstream section until the pressure at the downstream regulating station is sufficient to open the safety relief valve to the collapsible tank. If the pump continues to run, the collapsible tank will fill at a rate corresponding to the pumping rate. These described operations are the intended function of the pressure-regulating station and present no problem until the collapsible tank is completely filled. At that time some decision must be made as to whether the pumps should be shut down, the line should be reopened for flow, additional tankage should be provided at the downstream pressure-regulating station, or product should be vented to atmosphere at a rate corresponding to the pumping rate.

b. If the shutdown was initiated by a blockage of the pipeline downstream of the pressure-regulating station, the pressure will increase in the downstream section until either the pipe fails or the safety relief valve opens at the pressure-regulating station. If the safety relief valve at the pressure-regulating station opens to the collapsible tank, the operation is the same as that described in the first sequence. If the pipe fails downstream of the pressure-regulating station, in all probability the flow rate will increase sufficiently to actuate the excess-flow pilot and close the 3-in. control valve, and the operation will again be the same as that described in the first sequence.

The above problems will not occur if pumps are equipped with high-discharge pressure shutdown switches rather than high-discharge pressure throttling devices. During the initial adjustment of the regulating equipment, these pump controls may require manual overriding.

Pressure-regulating stations should not be used on a pipeline with positive displacement pumps. The reducing-pressure control pilot may tend to respond to pulses caused by positive displacement pumps and cause the control valve to respond in an undulating manner. This problem could be reduced by adjusting the Pneu-Trol to slow the speed of response of the 3-in. control valve.

To properly operate a pipeline with pressure-regulating stations, certain controls at the terminal end of the pipeline will be required. Each terminal point must be equipped with flow control and pressure relief. If flow control is not provided, the product velocity in the section of pipeline from the last pressure-regulating station to the terminal tankage may increase above the pumping velocity sufficiently to reduce downstream at the pressure regulating station, thus causing the reducing-pressure control pilot to open. This, in turn, opens the 3-in. control valve. When the control valve opens, the pressure in the upstream section is reduced, thus causing the next upstream pressure-regulating station to open. This sequence will be repeated for each succeeding pressure-regulating station until they are all open and the pipeline is operating as an open or a slack pipeline. This is an undesirable condition and could result in excessive mixture of product at interfaces.

A pressure-relief valve should be installed upstream of the block valves at the terminal end of the pipeline so that the section of pipe immediately upstream of the terminal end of the pipeline will be protected from overpressurization due to thermal expansion of the product, leakage of an upstream pressure-regulating station, or pressure surges.

The pressure-regulating station is designed to function properly at working pressures up to 1440 psig with clean product flowing in the system.

**11. Maintenance.** The pressure-regulating station will require a minimum of maintenance. The strainers should be cleaned regularly, and the control valves checked periodically for leakage. If a valve is found to be leaking, the O-ring seat should be changed. If this does not stop the leakage, the valve should be removed and replaced while the valve is returned to the manufacturer for repair, if possible.

Lubrication may be applied to the gear mechanisms of all ball valves once each month as a preventative type of maintenance. Do not use excessive amounts of lubricant.

**12. Cost and Cost Analysis.** The estimated cost to construct the unit in accordance with the Construction Drawings in Appendix B of this report is \$10,100. The estimated weight is 3200 lb. Estimated costs were based on the following premises:

a. Material costs were compiled from bills-of-material and certain quoted prices without provisions for price escalation. It was assumed that sales or use taxes will not be applicable to materials purchased by the federal government.

b. Fabrication costs were compiled from quoted prices and in-house estimates. Provisions for price escalation were not included.

c. Contingencies and omissions were included at 5 percent.

d. Costs for engineering services and for governmental contract management were not included.

**Cost Analysis.** A completely realistic cost analysis cannot be made because there is no item available on a DOD-wide basis which directly competes with the pressure-regulating station. Other solutions to this problem as discussed in the investigation offer competition but they do not have the capability to meet essential SDR requirements of the pressure-regulating station.

### III. DISCUSSION

**13. Requirements.** The military pressure-regulating station, as designed by Williams Brothers, Resource Sciences Center, satisfies all the essential SDR requirements. The SDR is presented as Appendix C for reference.

**14. Possible Requirements for Use with Flexible Hoselines.** The Army has developed and type classified a 4-in. assault lightweight flexible hose which can be laid with speed and economy of manpower. Tests indicate that weight limitations for the 4-in.

hose and the resulting thin wall (approximately 3/16 in.) make it necessary to take precautions against overpressurization.

When the hose is laid on a steep downhill slope for some distance, the pressure in the hose must be considered. If the difference in elevation from the crest to the downstream pumping unit is greater than 1350 ft, then use of a pressure regulator is recommended to prevent damage to the hose. With 1350-foot differences in elevation and pumping 0.725 specific-gravity motor gasoline, the no-flow static pressure that would develop is 435 psi; the burst pressure of 4-ft flexible hose is 450 psi.

At the present time there is a draft proposed Small Development Requirement (SDR) for Hose Assembly, 6-in., Collapsible, High-Pressure. Primary use of the 6-in. hose shall be as a replacement for the currently standard 4-in., fuel-handling hoseline outfit in establishing an initial bulk-distribution capability; and in the rapid extension of the pipe head from the head terminal of the installed system in support of rapid advances by elements of the field army; or to support suddenly increased requirements.

The 6-in. hose shall be capable of withstanding normal internal fluid pressures of at least 400 psi, and preliminary data indicate that the burst pressure should be about 800 psi. If the difference in elevation from the crest to the downstream pumping station is greater than 2400 ft, then the use of a pressure regulator would be recommended. With this difference in elevation, pumping 0.725 specific-gravity motor gasoline, the no-flow static pressure that would develop is 775 psi.

#### 15. Analysis of Unit Design Development.

a. The design configuration of Rockwell Model 503 valves was selected by the U. S. Army for detail design. A review revealed that one 3-in. Rockwell Model 503 control valve would be sufficient to control the four pipeline cases of operation. The 4-in. and 2-in. valves were removed, thus making the configuration more simple. Detail drawings of the final design are shown as Appendix B.

b. The orifice requirements for the excess-flow shutdown function of the pressure-regulating station were also reviewed. Two orifices would be required to handle the full range of flow rates for the four pipeline cases of operation. This situation was felt to be undesirable because of the necessity to provide a second orifice as a loose part and the necessity to change orifices in the field.

c. The possibility of using two orifices piped in parallel, and arranging valves to allow switching from one orifice to the other, was explored. This plan has two disadvantages. First, the space required to pipe the two orifices and the necessary valves in parallel would be excessive. This piping arrangement could probably be fitted into

the specified envelope size; however, workspace would be limited and congested. The second disadvantage to this piping arrangement is the increase in the weight of the unit due to the added piping and valves. The weight could possibly be kept within the specified limit; however, additional weight is considered to be undesirable.

d. Further exploratory engineering was conducted to determine if an orifice fitting could be obtained that would allow orifices to be changed easily and would provide storage for the orifice that was not in use. To be satisfactory, this fitting should allow the orifices to be switched without shutting down the line. The fitting should also provide storage and protection for the extra orifice plate.

e. Orifice fittings that perform all the required functions are manufactured in smaller sizes at the present time, but are not available in the 6-in. size required for the pressure-regulating station. Various orifice fittings were reviewed to determine if they could be altered to fulfill the desired application. It was determined that available orifice fittings could not be satisfactorily altered to meet the requirements.

f. The possibility of using two excess-flow pilots and only one orifice was considered. Two excess-flow pilots may be arranged to take signals from the same orifice and actuate at different preset pressure differentials. This arrangement requires very little additional space and adds only a small amount of weight. Additional flexibility is added by the use of two pilots.

g. In order to provide excess-flow shutdown capability for all four pipeline cases of operation with two pilots, at least one of the pilots must control a range of operating conditions. For the four specified cases of operation, the most effective arrangement would be to control the three lower-flow-rate cases of operation with one pilot to control the high-flow-rate cases of operation with the same pilot, and to control the high-flow-rate case of operation with a second pilot. This deduction is based on the design to preset the excess-flow pilots so that one control valve can handle four pipeline cases of operation without field adjustment to the excess-flow pilots.

h. The two-pilot arrangement will provide emergency shutdown for pipeline systems at flow rates of approximately 1300 GPM and 3000 GPM. These set points are particularly good for the two 8-in. and 12-in. pipeline cases of operation. For these cases of operation, the setting is sufficiently in excess of the anticipated flow rates to allow for possible fluctuations in flow rate, but in case of a downstream pipe failure, would not require a large increase in flow rate before shutting down the line. For the 6-in. pipeline, it may be desirable to readjust the excess-flow pilot.

i. When a pressure-regulating station is installed on a 6-in. pipeline with operating conditions similar to those described in Table II, an excess-flow pilot set for



approximately 1300 gpm would allow the flow rate to increase by 85 percent or more before shutting down the line. If it is desired to reduce the amount of product loss should a pipe failure occur, the excess-flow pilot can be manually adjusted so that it will actuate when the flow rate reaches approximately 800 gpm. It is not recommended that this adjustment be made in the field. The excess-flow pilot should be removed from the skid unit and taken to a shop for such adjustment. Pilot settings for given flow rates may be obtained from the curve shown on Fig. 21. This curve was plotted from calculated values and must be verified by an engineering design verification test conducted on a prototype unit.

## **16. Location.**

a. Pipelines can be operated safely on critical downhill grades if pressure-regulating stations are strategically installed. In order to determine the correct locations for the pressure-regulating stations, an accurate profile of the pipeline route is required and pipeline operating conditions must be known. In locating pressure-regulating stations, calculations should be based on the heaviest product to be transported by the pipeline.

b. Contract DAAK02-70-C-0119 designates the design operating point for the portable pressure-regulating system to be based on regular motor gasoline with a specific gravity of 0.725 and kinematic viscosity of 0.62 centistokes at 60° F. The design is also based on controlling military aviation gasoline, JP 4, kerosene, and diesel.

c. The specific gravity of a petroleum product may vary from batch to batch. Most refined petroleum products are considered acceptable for a given range of specific gravities. Because the location of the pressure-regulating stations is determined by the weight of the product in the pipeline, it is necessary to make calculations for the location of pressure-regulating stations using the upper limit of the acceptable specific-gravity range. If more than one product is to be handled by the pipeline, the upper specific-gravity limit of the product having the highest specific-gravity range should be used.

d. The pressure-regulating stations must be located on the basis of vertical elevation difference plus pump discharge pressure. Although the horizontal travel of a downhill slope may be sufficient to dissipate much of the static head through friction loss in flowing conditions, it has no effect on the static head when the line is shut down. The most critical conditions for downhill sections of pipeline frequently occur when the line is shut down since no part of the static head is dissipated due to friction. This does not necessarily hold true for a downhill section followed by an uphill section with no intermediate pump stations. For a critical downhill section followed by an uphill section with no intermediate pump station, the pressure at the lowest point may be

FOR ORFICE WITH 3.803" BORE  
IN PIPE WITH 6.065" I.D.  
PRESSURE TAP AT VENA CONTRACTA

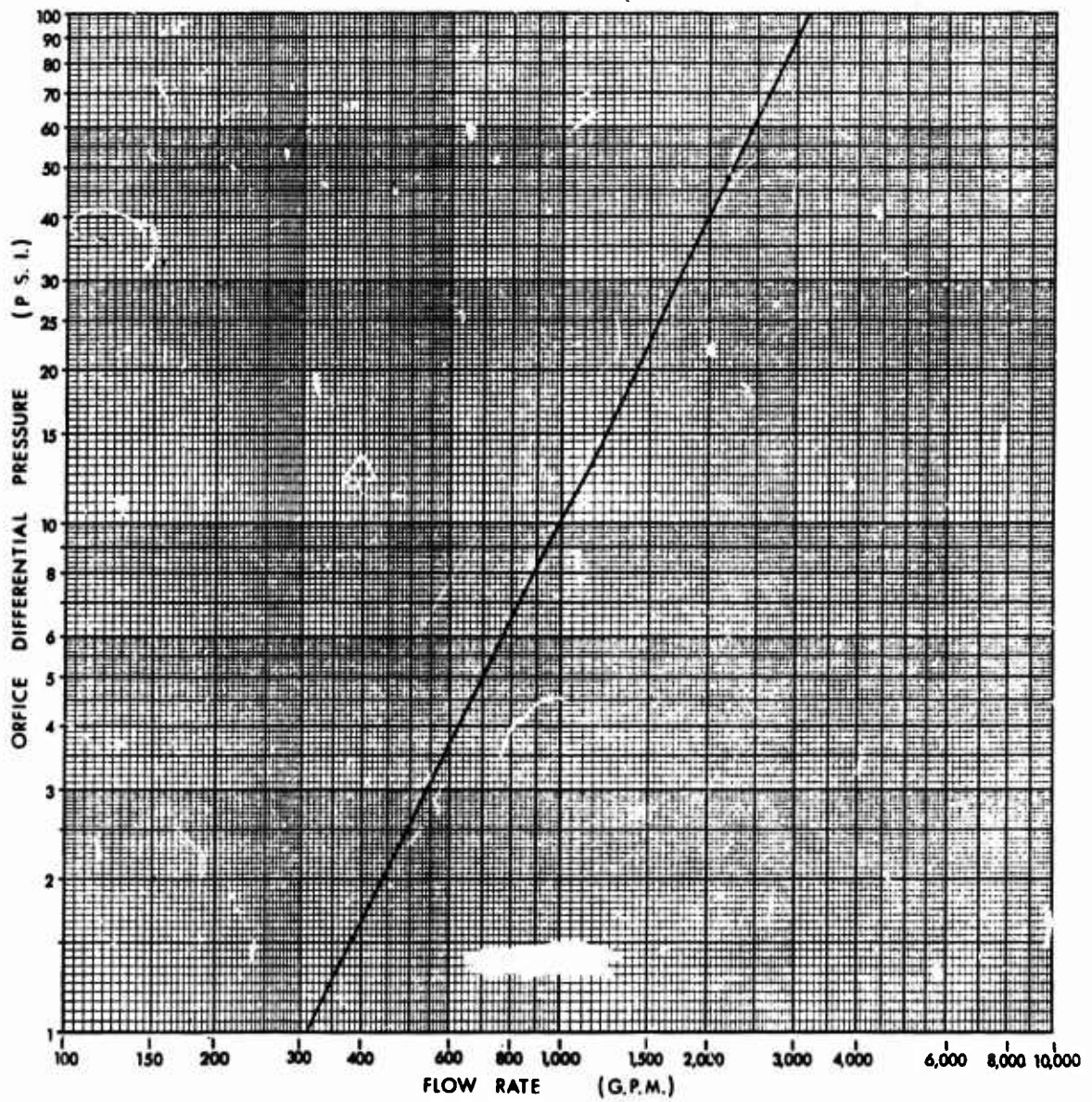


Fig. 21. Flow rate versus differential pressure.

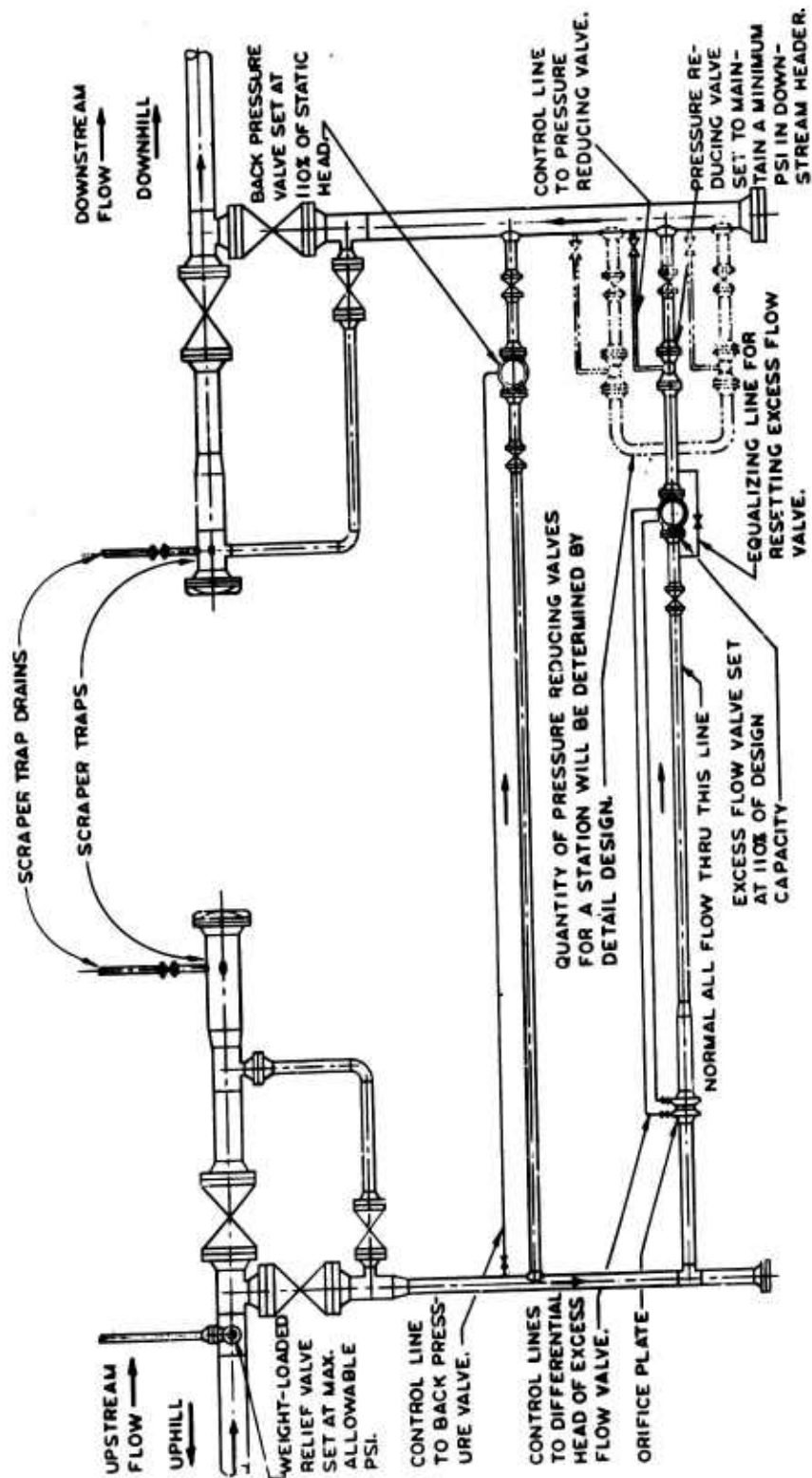


Fig. 22. Pressure-reducing station on Bolivian pipeline—schematic layout.

higher for the flowing condition than for the shutdown condition, depending on where the lowest point is located.

#### **17. Commercial Adaption of Military Version of Pressure-Reducing Station.**

Although the fabrication and testing of a prototype military pressure-regulating station by MERDC is remote, one commercial version has been built and installed. The commercial regulating station was installed in the Sicasica-Arica leg of the Bolivian pipeline. This pipeline originates at Sicasica, Bolivia, and extends 215 miles across the Alto Plano and Andean mountains to an offshore marine loading terminal at Arica, Chile. It was designed and built by the Williams Brothers Engineering Company.

Four pressure-reducing stations were used to dissipate the total static head of 4972 psi, limiting maximum static head between stations to safe operating levels. The operation of each pressure-reducing station is designed to be automatic, self-regulating, and unattended, except when excess-flow conditions actuate an excess-flow valve, shutting down the pipeline. Manual reset is then required to reestablish flow. The motive power for all control operations is supplied by hydraulic pressure in the pipeline.

All control valves and fittings were selected to meet 900-16 ASA Standards where applicable. Figure 22 is a schematic layout of a typical pressure-reducing station used on the Bolivian pipeline illustrating the manner in which the components were assembled. Other than control equipment, the fittings used are typical of standard receiving and sending scraper trap assemblies.

The stations were custom designed for their particular location, whereas the MERDC design is designed for worldwide utilization.

### **IV. CONCLUSIONS**

#### **18. Conclusions. It is concluded that:**

- a. All essential Army (SDR) requirements for a military, pressure-regulating station can be satisfied with the designed regulating station.
- b. The primary military feature of the designed pressure-regulating station is that it can be utilized worldwide. A ready-to-install pressure-regulating station eliminates the necessity for custom design for each location.

c. The workability of the designed military pressure-regulating station has been partially verified by the installation and operation of a commercial design of similar configuration.

d. The designed pressure-regulating station should be satisfactory for military use.

## **LITERATURE CITED**

1. Williams Brothers Engineering Co., "Portable Pressure-Regulating Systems for Critical Downhill Sections of 6-, 8-, and 12-inch Military Petroleum Pipelines," Report No. 2, September 1970 (USAMERDC Contract DAAK02-70-C-0119).
2. U. S. Army, Department of the Army Approved Small Development Requirement (SDR) for a Family of Pressure-Regulating Equipment, 6-, 8-, 12-Inch, Military Petroleum-Products Pipelines, 8 November 1965.
3. Text, U. S. Army Engineer School, Fort Belvoir, Virginia, ST 5-188, "Structures and Utilities, Theatre of Operations Construction," Vol. B, January 1965.

## **APPENDIX A**

### **SPECIFICATIONS**

#### **CONSTRUCTION SPECIFICATIONS**

##### **A. General.**

1. The following specifications are applicable to the construction of a prototype Pressure-Regulating System. This system is envisioned as a unit constructed to the generally accepted good workmanship practices of the pipeline industry.

2. Should any actual conflict or conflicts exist between or among the provisions of any of the Specifications or Construction Drawings, the priority in which the various provisions shall govern, one over the other, is as follows:

- a. Construction Drawings.
- b. Construction Specifications.

##### **B. Pipe Work.**

1. Contractor shall fabricate all piping and install all valves and fittings as called for on the Construction Drawings. Such piping shall be installed true and level or plumb. Where slope is required, each slope shall be maintained without sags in the piping run.

2. Contractor shall insure that piping assemblies are under no strain prior to final bolting or welding. Misalignment will not be permitted.

3. Contractor shall insure that all equipment and piping are thoroughly swabbed clean of all dust, refuse, welding spatter, etc., prior to tie-in or final bolting.

##### **C. Equipment Installations.**

Contractor shall furnish all labor, tools, and equipment necessary to install all items of machinery and equipment requiring permanent installation. Contractor shall align, level, set, and properly attach all such equipment to conform with the location, dimensions, and elevations as shown on the Construction Drawings and in accordance with the manufacturer's recommendations. Contractor shall adjust equipment requiring shop calibration as indicated on the Construction Drawings.

**1. Flanged Connections.**

a. Contractor shall insure that all flange faces are parallel and correctly centered prior to final bolting. Force will not be permitted in attaining alignment and a gasket of the proper size shall be installed in each joint.

b. Bolts shall be tightened in diagonal sequence and shall be centered with equal threads visible on both sides. Bolts shall be uniformly tightened to produce a leakproof joint but shall not be tightened excessively so as to cause yield or permanent set. It is suggested that a torque wrench be used for bolt tightening.

c. Bolting materials delivered to and received by Contractor shall be immediately treated with a mixture of oil and graphite to control rust, as directed by Inspector.

**2. Flared Tubing.**

a. Contractor will furnish all necessary tube-cutting and -flaring equipment to make required flared lengths. Damaged flares shall be cut off and the tubing reflared, at no expense to the Contracting office.

b. Contractor shall properly align all flared tubing joints.

c. Flared tubing connections shall be made up tight with teflon tape. Particles of teflon tape shall not be allowed to enter the tubing or pilot lines.

**3. Threaded Connections.**

a. Contractor will furnish all necessary pipe-cutting and -threading equipment to make required threaded lengths. Damaged threads shall be cut off and the pipe rethreaded, at no expense to the Contracting Office.

b. Contractor shall properly align all threaded joints. Pipe entering unions shall be true to centerline so that the union does not have to be forced for makeup. Threaded pipe shall not project through fittings to cause interference with valves or other operating mechanisms.

c. Threaded connections shall be made up tight with teflon tape.

d. Close nipples shall not be used unless absolutely necessary.

e. Pipe wrenches shall not excessively scar the pipe.



#### **4. Welded Connections.**

a. All welding shall be performed and all welders shall be qualified in accordance with API Standard 1104, Latest Edition, "Standard for Field Welding of Pipe Lines and Related Facilities," which is hereby considered a part of these Specifications.

b. Alignment between adjoining sections of pipe or fittings shall be so performed that the axial centerline coincides, unless otherwise required by the Construction Drawings.

c. All welds made during the performance of the work shall be subject to radiographic examination by a third party service. If, as a result of such examination, any weld(s) are shown to be defective in the sole opinion of the Inspector, such defective welds shall be removed and replaced at no expense to the Contracting office. Pipe sections, flanges, and fittings damaged or destroyed thereby shall be replaced in kind by Contractor at no expense to the Contracting office.

#### **5. Defects.**

a. If laminations, split ends, or other pipe defects are discovered, that length of pipe containing the defect shall be cropped, repaired, or removed at the direction of Inspector.

#### **6. Pressure Testing.**

a. Contractor shall furnish necessary water pump, gages, and other material and equipment to test the piping system for leaks after complete fabrication and assembly of the unit. The water test pressure will be 1440 psig. Test pressure will be held for a period of four (4) hours with no loss of pressure. Valves to all pilots shall be closed before water test is begun.

b. Equipment used for testing purposes must be a type approved by Inspector.

c. Inspector must be completely satisfied with performance and results of test before work will be approved.

#### **7. Certification of Welders.**

a. Contractor shall furnish pulling machine and all other material necessary to test all welders to be employed on the job. All welders will be tested in the presence of Inspector, and after welders have been tested and samples have been broken in

accordance with API Standard 1104, Contractor will furnish written certification of each test to Inspector. Testing shall be at Contractor's expense.

**D. Structural Steel Work.**

1. **Scope.** This Specification covers detailing, fabrication and erection of structural steel. If there is a conflict between this Specification and the Drawings, the Drawings shall govern.

2. **Applicable Publications.** The latest revision to the following publications shall govern the work.

- a. "Specifications for the Design, Fabrication, and Erection of Structural Steel for Buildings" of the AISC.
- b. AWS Standard Code D 1.0.
- c. "Code of Standard Practice for Steel Buildings and Bridges" of the AISC.
- d. AISI's "Light Gage Cold-Formed Steel Design Manual."
- e. Local building codes.

3. **Connections.**

a. **General.** Design of connections not shown in detail on the design drawings shall be the responsibility of the fabricator.

b. **Beam Connections.** Unless shown otherwise, standard frame connections as shown in Part 4, Table 1 of the AISC Manual shall be used. The connections shall have the maximum number of bolts shown in the table or equivalent welds. Field connections shall be bolted unless noted.

Bolted connections shall be designed as bearing type with the threads included in the shear plane. Bolts shall be 3/4-in. diameter, ASTM A325. One hardened washer shall be provided for each bolt. Bolt holes shall be 13/16-in. diameter.

c. **Welded Connections.** Welded connections shall be made with E-70 electrodes. All welding shall conform to the American Welding Society Standards and as modified by the AISC Specifications. If structural steel is to be galvanized, all connections shall be seal welded in addition to structural weld.

d. **Miscellaneous Connections.** Bolts for girts and channel purlins connections shall be 5/8-in. diameter machine bolts.

e. **Axially Loaded Bracing.** Minimum connections for axially loaded bracing members, where the loads are not indicated on the drawings, shall be designed for 10,000 lb or one-half the tensile capacity of the net area of the member. No fewer than two bolts may be used in any connection.

f. **Gusset Plates.** The minimum thickness of gusset plates shall be 1/16-in. greater than the largest connecting member.

g. **Shop.** Shop connections may be welded or high-strength bolted.

h. **Field.** Field connections shall be bolted unless otherwise shown on the drawings. Field-drilled holes required for erection shall be drilled and reamed.

4. **Qualifications of Welders.** Welding procedures which conform to the provisions of Section 2, 3, and 4 of the AWS Code 1.0 shall be deemed prequalified and are exempt from tests or qualifications. Except for the above, welders must be qualified per AWS Code B3.0.

5. **Fabrication.**

a. **Assembly.** Structural material shall be fabricated and assembled in the shop to the greatest extent possible. Parts not completely bolted in the shop shall be secured by bolts, insofar as practicable, to prevent damage in shipment and handling.

b. **Fitting.** Radius for reentrant flame cuts shall be 3/4-in. minimum except in small members. Shearing, flame cutting, and chipping shall be done carefully and accurately. Sole plates of beams and girders shall have full contact with the flanges. Stiffeners shall have full contact with the flanges. Stiffeners shall be fitted neatly between the flanges of girders, and, where tight fits are required to transmit bearing, the ends of the stiffeners shall be milled or ground to secure an even bearing against the flange angles. Fillers under end angles shall not project beyond the backs of the angles. The clearance between the ends of spliced web plates shall not exceed 1/4-in. Only high-strength bolts installed as friction-type connections prior to welding may be considered as sharing the stress with the welds.

c. **Holes.** Holes shall be drilled, subpunched and reamed, or punched at right angles to the surface of the metal and shall not be made or enlarged by burning. Holes in base or bearing plates shall be drilled. Holes shall be clean-cut without torn or ragged edges. Outside burrs resulting from drilling or reaming operation shall be removed.

d. **Compression Members.** Columns and other compression members shall have milled ends for full bearing at splices and base plates. Square cut columns may be accepted if approved by the Contracting Office. Milled surfaces shall be protected for shipment and storage in the field.

e. **Cutting.** Rough edges and burrs left from flame cutting, shearing, or sawing structural members, handrail, floor plate, etc., shall be ground smooth.

6. **Storage.** Structural material, either plain or fabricated, shall be stored above the ground upon platforms, skids, or other supports. Material shall be kept free from dirt, grease, and other foreign matter and shall be protected from corrosion.

7. **Assembly.** After assembly the various members forming parts of a completed frame or structure shall be aligned and adjusted accurately before being permanently fastened. Tolerances shall conform to AISC, "Code of Standard Practice." Fastening of splices of compression members shall be done after the abutting surfaces have been brought completely into contact. Bearing surfaces and surfaces that will be in permanent contact shall be cleaned before the members are assembled. As erection progresses, the work shall be securely fastened or braced to take care of all dead load and erection stresses. Unless removal is required, all erection bolts used in welded construction may be tightened securely and left in place. If erection bolts are removed, the holes shall be filled with plug welds.

a. **Driftpins.** Driftpins may be used only to bring together the several parts and shall not be used in such manner as to distort or damage the metal.

b. **High-Strength Bolts.** Assembly of joints using ASTM A325 bolts shall conform to the AISC Specification for structural joints using A325.

c. **Unfinished Bolting.** Bolts shall be placed accurately into the holes without damaging the threads or bolt heads. Bolt heads and nuts shall rest squarely against the metal. Where bolts are to be used on beveled surfaces having slopes greater than 1 in 20 with a plane normal to the bolt axis, beveled washers shall be provided to give full bearing to the head or nut. Bolt heads and nuts shall be drawn tight against the work with a suitable wrench. Bolt heads shall be tapped with a hammer while the nut is being tightened.

d. **Cutting.** Fabrication errors but not mislocated bolt holes may be corrected by use of a cutting torch if the Inspector specifically approves. Workmanship shall be of shop caliber and shall fully develop strength of spliced member or connection.

e. **Damage to Coatings.** Any damage to coatings sustained during erection shall be repaired in the manner directed by the Inspector at the Erection Contractor's expense.

**E. Cleaning and Painting.**

1. **General.** Work under this subsection shall include the preparation of surfaces and the application of primer and paint to all surfaces that require painting. Contractor shall furnish all necessary labor, supervision, tools, equipment, and materials to paint all surfaces that require painting as called for by these Specifications. Contractor shall furnish all paint and primer.

2. **Surfaces Requiring Painting.**

a. All piping and structural steel shall be cleaned and painted. All valves and pilots shall be cleaned and painted.

b. All dials, indicators, and adjustment screws shall be masked off and protected from the cleaning and painting operation. All nameplates or operational data which are attached or stenciled on equipment or machinery that is to be painted shall be masked off before painting operation begins. When Contractor is in doubt as to what should or should not be masked off, he should request a decision from the Inspector.

3. **Cleaning.**

a. All surfaces to be painted shall be thoroughly cleaned of all grease, oil, rust, slag, dirt, and other foreign matter that will prevent complete adherence of primer or paint to the base material of the surface.

b. All surfaces shall be cleaned and prepared for painting in accordance with MIL-T-704.

4. **Painting.**

a. Paint shall be applied in strict accordance with the instructions of the manufacturer. Paint shall not be applied during rainy, damp, or frosty weather nor during periods when sand or dust are present in the air. Paint shall not be applied unless the surface being painted is thoroughly dry.

b. All primer and paint application shall be done in accordance with MIL-T-704.

**5. Paint.**

- a. All primer and paint shall comply with MIL-T-704 and FED-STD No. 595.

**6. Identification Markings and Instruction Markings.**

- a. All identification markings shall comply with MIL-STD-130 (identification markings of U. S. Military Property).

b. The inlet flange shall be clearly stenciled with the word "inlet" and the outlet flange shall be clearly stenciled with the word "outlet."

c. All ball valves and control valves shall have an arrow indicating the direction of flow clearly painted on the valve body.

**F. Material Specification.**

**1. General.**

a. All material specified in the Bills-of-Material on the Construction Drawings shall be furnished as specified in the Bills-of-Material on the Construction Drawings unless specifically mentioned in this Specification.

b. This Specification is to fully specify material listed but not completely detailed in the Bills-of-Material on the Construction Drawings, and to specify material not listed in the Bills-of-Material on the Construction Drawings.

c. Should any actual conflict or conflicts exist between or among these Specifications and Construction Drawings, the Construction Drawings shall govern.

**2. Rockwell Model 503-I Control Valves (2-in. and 3-in.)**

a. Rockwell 2-in. and 3-in. Model 503-I control valves manufactured by the Rockwell Manufacturing Company of Pittsburgh, Pennsylvania, shall have 600-lb ASA raise-faced flanges on each end. Each valve shall be steel bodied and rated for 1440 psi working pressure. Each valve shall be equipped with stainless-steel-piston, low-temperature O-rings (-50° F to +150° F), and a ductile iron indicating extension.

**3. Rockwell Model 2750 Pressure-Reducing Pilot.**

a. Rockwell Model 2750 pressure-reducing pilots manufactured by the Rockwell Manufacturing Company of Pittsburgh, Pennsylvania, shall have steel bodies

and be rated for 1440 psi working pressure. Each pilot shall have stainless steel trim and special low-temperature O-rings (-50° F to +150° F). Each pilot shall be equipped with a dial indicator for pilot position and a spring with range of 50 to 1000 psi.

4. Rockwell Model 2760 Back-Pressure Pilot.

a. Rockwell Model 2760 back-pressure pilots manufactured by the Rockwell Manufacturing Company of Pittsburgh, Pennsylvania, shall have steel bodies and be rated for 1440 psi working pressure. Each pilot shall have stainless steel trim and special low-temperature O-rings (-50° F to +150° F). Each pilot shall be equipped with a dial indicator for pilot position and a spring with range of 300 to 1500 psi.

5. Rockwell Model 2780 S Flow-Rate Pilot.

a. Rockwell Model 2780 S flow-rate pilots manufactured by the Rockwell Manufacturing Company of Pittsburgh, Pennsylvania, shall have steel bodies and be rated for 1440 psi working pressure. Each pilot shall have stainless steel trim and special low-temperature O-rings (-50° F to +150° F). Each pilot shall be equipped with a spring with range of 5 to 100 psi. Each pilot shall be normally open and a trip lever operated to close at set differential pressure and remain closed until manually reset.

6. Pneu-Trol Valves.

a. Pneu-Trol valves shall be Model F25S steel flow-control valves manufactured by Auto-Ponents Division of Deltrol Corporation, Bellwood, Illinois, or equal, rated for 5000 psi working pressure. Constructed for free flow one direction (in) and control flow the other direction (out).

7. Combination Needle Valve and Strainer.

a. Combination needle valve and strainer shall be Model 460680 S manufactured by the Rockwell Manufacturing Company of Pittsburgh, Pennsylvania, or equal, and shall be rated for 1440 psi working pressure.

8. Flanges and Other Weld Fittings.

a. All flanges shall comply with the American Standards Association (now the American National Standards Institute) Standard B 16.5, Latest Edition, Steel Pipe Flanges and Flanged Fittings, Class 600.

b. All other weld fittings shall comply with American Standards Association (now the American National Standards Institute) Standard B 16.9, Latest Edition,

## **Wrought Steel Buttwelding Fittings.**

### **9. Flared Tubing Fittings.**

a. All tubing fittings shall conform to MIL-F-5509, fittings, flared tube, fluid connection.

10. **Structural Steel Materials.** All material shall be of new stock and cut from a single rolled unit. No substitution of material shall be allowed without written approval from the Contracting Office.

a. **Structural Steel.** Structural steel shapes and plates shall conform to ASTM A36 except as noted on drawings.

b. **High-Strength Bolts.** Bolts, nuts, and washers shall conform to ASTM A325 high-strength bolts.

c. **Machine Bolts.** Bolts and nuts shall conform to ASTM A307 specification for low-carbon steel externally and internally threaded standard fasteners.

d. **Welding Electrodes.** Electrodes shall conform to ASTM A233 Series E70xx.

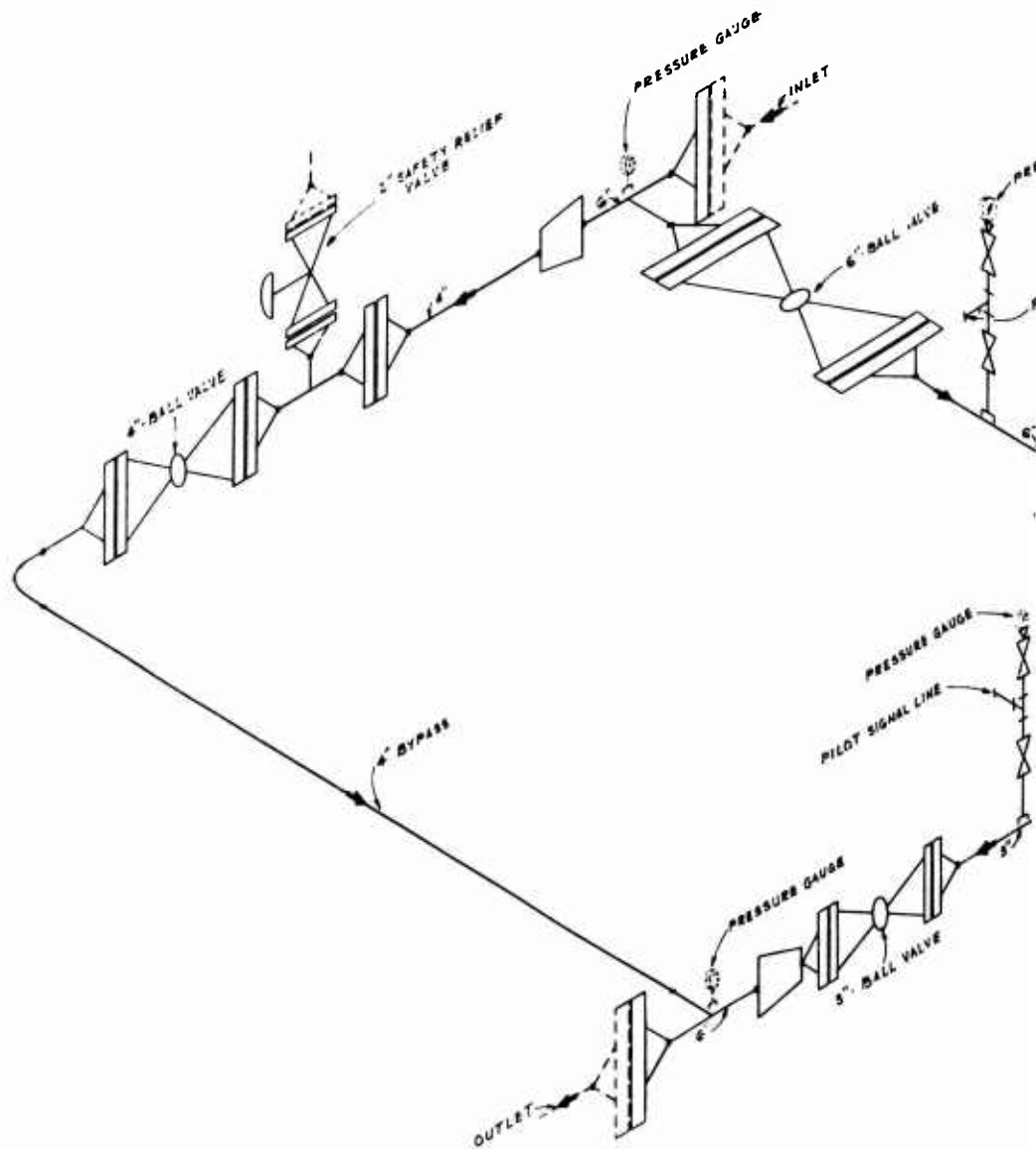
e. **Floor Grating.** Floor grating, if specified and not otherwise noted, shall be Type GW100 (1 in. by 3/16 in.) as manufactured by the Kerrigan Iron Works Company, or approved equal. Fabricator to provide standard grating clips and self-tapping screws.

f. **Floor Plate.** Floor plate, unless noted otherwise, shall be checkered, 1/4-in., raised pattern.

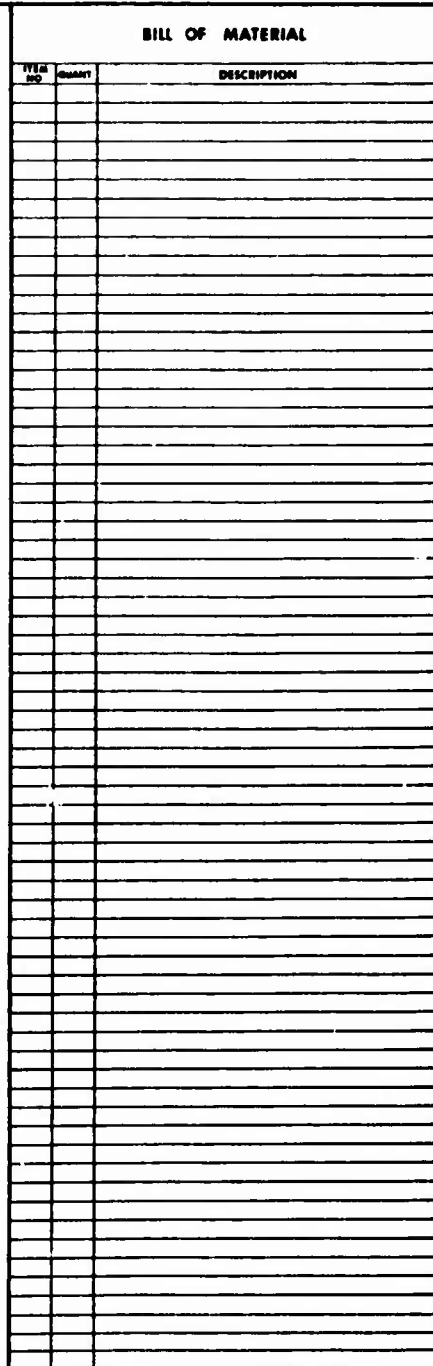
g. **Certification and Marking.** Certified mill test reports of all ASTM materials used in the work shall be kept on file by the fabricator for inspection. Steel shall be marked as per ASTM A6 general requirement for delivery of rolled steel plates, shapes, sheet piling, and bars for structural use.



DATE 02-06-2000

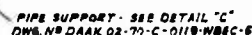
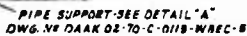
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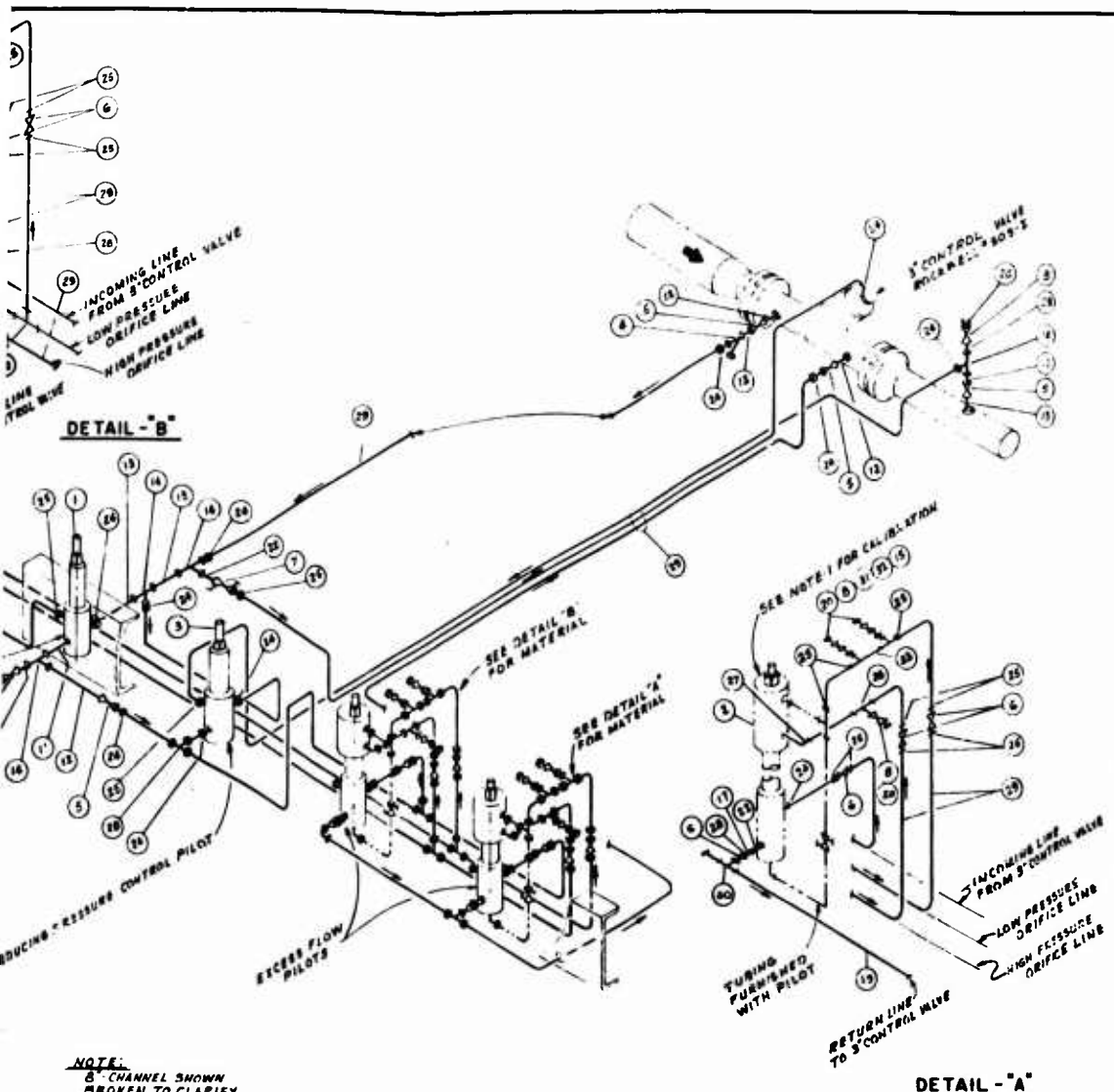
<b>WILLIAMS BROTHERS ENGINEERING COMPANY</b> ENGINEERS - CONSULTANTS TULSA, OKLAHOMA				
PIPING SCHEMATIC				
APPROVED _____ DATE	_____ NO.	_____ REVISION NO.	_____ DRAWING NO.	
_____ DAAK OR-70-C-018-WBEC-1		_____ REVISION		

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APPROVED	DATE	NO	ISSUING NO
		1896	DAK 02-70-C-0419-WREC-2





NOTE:  
B\"/>

CONTROL TUBING SCHEMATIC  
FOR 3\"/>

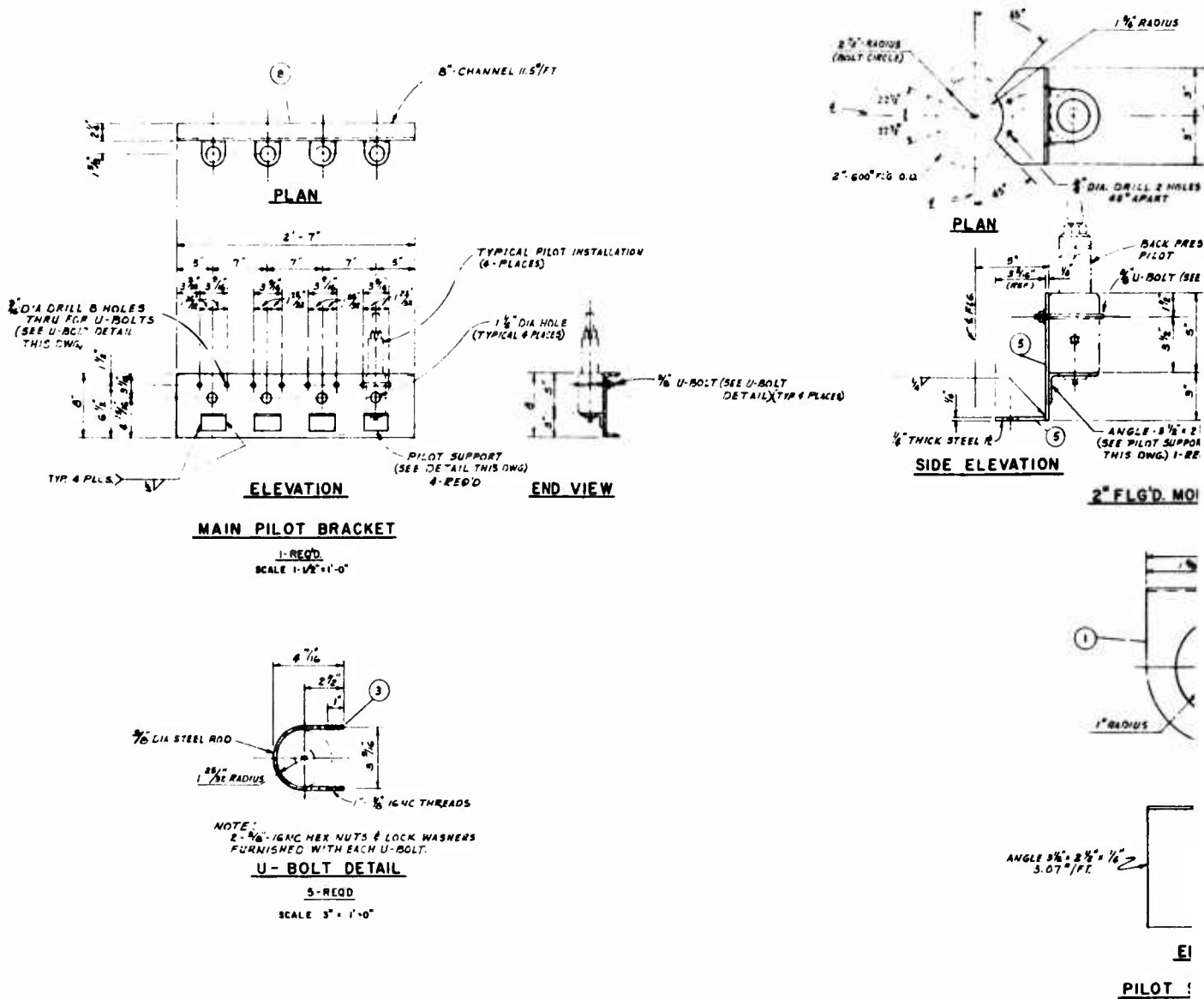
BILL OF MATERIAL

ITEM NO.	QUANTITY	DESCRIPTION
1	2	Pilot, Back Pressure, Rockwell Model 2750
2	2	Pilot, Excess Flow, Rockwell Model 2700
3	1	Pilot Pressure, Control, Rockwell Model 2750
4	2	Strainer, Scr., 1/2\"/>
5	12	Valves, Needle, Scr., 1/2\"/>
6	9	Valves, Needle, Scr., 3/8\"/>
7	3	Valves, Needle, Scr., 1/2\"/>
8	0	Valves, Needle, Scr., 1/2\"/>
9	0	Valves, Needle, Scr., 1/2\"/>
10	2	Diaphragm, 1/2\"/>
11	1	Diaphragm, 1/2\"/>
12	20	Diaphragm, 1/2\"/>
13	0	Diaphragm, 1/2\"/>
14	0	Tube, Pipe, Scr., 1/2\"/>
15	5	Tube, Pipe, Scr., 1/2\"/>
16	0	Elbow, Pipe, Scr., 1/2\"/>
17	2	Union, 1/2\"/>
18	3	Plug, Pipe, 1/2\"/>
19	0	Plug, Pipe, 1/2\"/>
20	0	Plug, Pipe, 1/2\"/>
21	0	Plug, Pipe, 1/2\"/>
22	4	Diaphragm, 1/2\"/>
23	2	Diaphragm, 1/2\"/>
24	20	Diaphragm, 1/2\"/>
25	20	Diaphragm, 1/2\"/>
26	7	Diaphragm, 1/2\"/>
27	2	Diaphragm, 1/2\"/>
28	4	Diaphragm, 1/2\"/>
29	0	Diaphragm, 1/2\"/>
30	1	Diaphragm, 1/2\"/>
31	0	Diaphragm, 1/2\"/>
32	4	Diaphragm, 1/2\"/>

**WILLIAMS BROTHERS ENGINEERING COMPANY**  
ENGINEERS - CONSULTANTS  
TULSA, OKLAHOMA

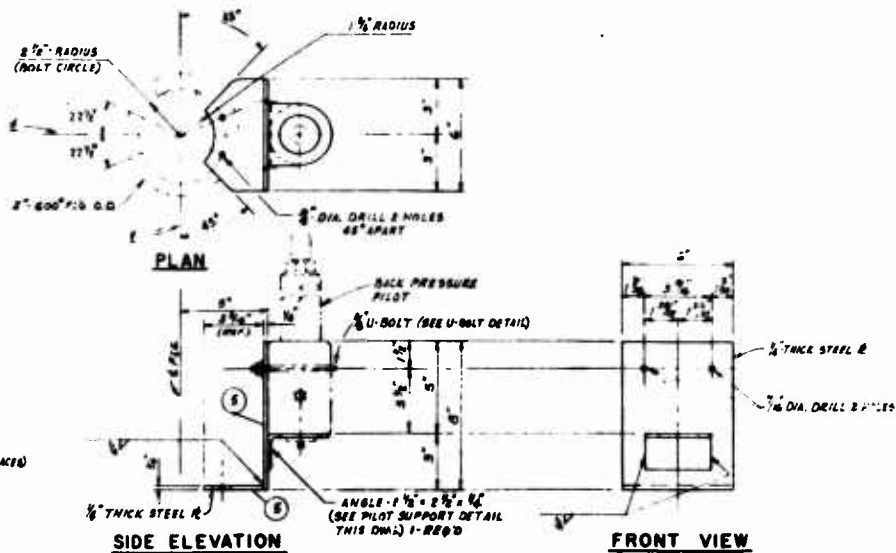
**PILOT TUBING SCHEMATIC**

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DRAWING NO: DAAK 02-70-C-019-WDEC-3

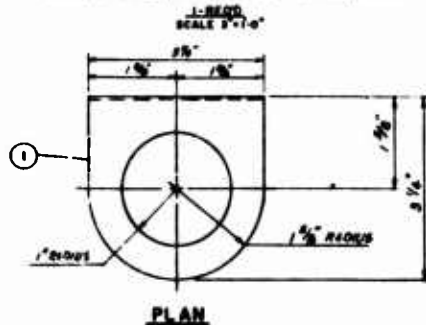


GENERAL NOTES		REFERENCE DRAWINGS			
NUMBER	TITLE	NO	DESCRIPTION		
DAWG 02 70-C 019-W-SEC-1	PIPING SCHEMATIC				
DAWG 02 70-C 019-W-SEC-2	PIPING PLAN & SECTIONS				
DAWG 02 70-C 019-W-SEC-3	PILOT TUBING SCHEMATIC				
DAWG 02 70-C 019-W-SEC-4	PIPING ORIS & FABRICATION DETAILS				

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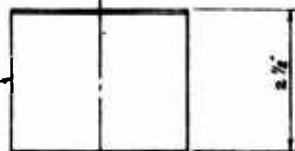


2" FLGD. MOUNTED PILOT BRACKET



PLAN

ANGLE  $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{1}{2}''$   
3.07" / FT



ELEVATION

PILOT SUPPORT DETAIL

3-REQD  
SCALE 3/4" = 1'-0"

# BILL OF MATERIAL

ITEM NO.	QUANTITY	DESCRIPTION
1	1'-3 1/2"	Angle, 2 1/2" x 2 1/2" x 1/4" TH... 2.010 LBS
2		
3	4'-4 1/2"	Hex. Steel 3/8" B O (For U-Bolts)
4	10	Nuts, 3/8" 1000 Heavy Hex (For U-Bolts)
5	1	Plate, Steel, 1/4" LG x 6" WIDE x 1/4" THICK
6		
7	10	Nutwash, Lead (For U-Bolts)
8	4'-4 1/2"	Channel, 8"-11.5 DTL.

REFERENCE DRAWINGS			REVISIONS				ENGINEERING RECORD			
NO.	REVISION	DATE	BY	DATE	CHKD	DATE	SCALE	NOTED	DATE	BY
1	1	1-10-70	W.B.C.				1/4" = 1'-0"			
2	2	1-10-70	W.B.C.				1/4" = 1'-0"			
3	3	1-10-70	W.B.C.				1/4" = 1'-0"			
4	4	1-10-70	W.B.C.				1/4" = 1'-0"			
5	5	1-10-70	W.B.C.				1/4" = 1'-0"			
6	6	1-10-70	W.B.C.				1/4" = 1'-0"			
7	7	1-10-70	W.B.C.				1/4" = 1'-0"			
8	8	1-10-70	W.B.C.				1/4" = 1'-0"			
9	9	1-10-70	W.B.C.				1/4" = 1'-0"			
10	10	1-10-70	W.B.C.				1/4" = 1'-0"			

WILLIAMS BROTHERS ENGINEERING COMPANY  
ENGINEERS - CONSULTANTS  
TULSA, OKLAHOMA

PILOT BRACKET  
& SUPPORT DETAILS

APPROVED	DATE	1896	DAWG	1896	DATE	1896	DATE	1896
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## APPENDIX C

Department of the Army  
Headquarters  
United States Army Combat Developments Command  
Fort Belvoir, Virginia 22060

CDCMR-O

8 November 1965

**SUBJECT:** Department of the Army (DA) Approved Small Development Requirement (SDR) for a Family of Pressure Regulating Equipment, 6-, 8-, 12-Inch, Military Petroleum Products Pipelines.

**TO:** See Distribution

1. Reference letter, CDCMR-O, Headquarters, US Army Combat Developments Command, 24 June 1965, subject: Proposed Small Development Requirement for a Family of Pressure-Regulating Equipment, 6-, 8-, 12-Inch, Military Petroleum-Products Pipelines, with 1st Indorsement, CRD-L 191, Office of the Chief of Research and Development, Department of the Army, 22 October 1965.

2. The proposed SDR, submitted to Department of the Army and furnished to information addressees by referenced letter, was approved by referenced 1st Indorsement. Department of the Army comments have been incorporated in the approved SDR, which is attached as Inclosure 1.

3. The US Army Combat Developments Command Combat Service Support Group is assigned proponentcy for the attached SDR.

4. This materiel requirement is identified as USACDC Action Control Number 6820 and supports the following:

- |                         |  |
|-------------------------|--|
| a. Army concept program | Army 75                                    |
| b. Army missions        | 1: High-intensity warfare                  |
|                         | 2: Mid-intensity warfare                   |
|                         | 3: Low-intensity warfare, Type I           |
|                         | 4: Low-intensity warfare, Type II          |
|                         | 6: Military aid to U. S. civil authorities |
|                         | 7: Complementing of allied land-power      |

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c. Phase

Materiel

d. Function

Service support

FOR THE COMMANDER:

1 Incl  
Approved SDR

/s/t/ BYRON R. HAWKINS  
Major, AGC  
Asst Adj Gen

DISTRIBUTION:  
"H"

**Department of the Army (DA) Approved Small Development Requirement (SDR) for  
a Family of Pressure-Regulating Equipment, 6-, 8-, and 12-Inch,  
Military Petroleum-Products Pipelines**

1. Paragraph Number. 169f(1)
2. Purpose and Operational Characteristics.

a. Purpose. To develop a Family of pressure-regulating equipment for use with the 6-, 8-, and 12-in. coupled and welded military petroleum pipeline systems.

b. Operational Characteristics. This pressure-regulating equipment will be used to control the pressure-regulating problems in military petroleum pipeline systems constructed over rugged terrain. Pressure is built up in all pipelines from opening and closing block valves, starting and stopping pumps, and when the line traverses deep gorges and long downhill slopes. Pressure-regulating equipment is necessary when static pressure exceeds the following:

<u>Size Pipe</u>	<u>Type</u>	<u>Maximum Operating Pressure</u>
6-in.	Coupled	600 psi
8-in.	Coupled	500 psi
8-in.	Welded	1340 psi
12-in.	Coupled	400 psi
12-in.	Welded	1340 psi

The equipment will be used on a continuous or intermittent basis in all areas where military petroleum pipelines are deployed. Such operations will include around-the-clock and all-weather use. It is essential that the pressure-regulating equipment possess the following characteristics:

(1) Be capable of being installed and operated in climatic conditions as defined in Paragraphs 7a, b, and c of AR 705-15, with change 1, "Operation of Materiel Under Extreme Conditions of Environment."

(2) Be capable of operating unattended.

(3) Be capable of blocking flow to minimize fuel loss in event of line break.

(4) Be capable of protecting the pipeline from excess line pressure which results from opening and closing block valves either upstream or downstream.

(5) Be capable of protecting the pipeline from excess line pressure which results from starting and stopping pumps either upstream or downstream.

(6) Be designed to permit passage of pipeline scrapers or incorporate provisions for receiving and sending scrapers.

(7) Be capable of operating to protect the pipeline from excess pressure created by static, steady-state flow and transient-flow conditions.

(8) The weight of the pressure-regulating equipment will be consistent with present day scientific knowledge keeping dependable trouble-free service as the first consideration when this development is pursued.

(9) Configuration of the pressure-regulating equipment will be such that the installed facilities will present as low a silhouette as possible.

(10) The equipment shall be suitable for transport by vehicles available within the Type Field Army.

(11) Be designed so that pressure losses throughout the pressure-regulating equipment are minimized. Completely telemetered system dictated.

(12) Allow for thermal expansion and contraction of line fill.

(13) Except for expendable interior components, the pressure-regulating equipment shall have an effective life of at least 5 years of continuous or intermittent service under the environmental requirements of Paragraphs 7a, b, and c, AR 705-15, with change 1.

c. Operational Information.

(1) Planned deployment. The proposed pressure-regulating equipment will be a class IV item of issue to be used when static pressure exceeds design operating pressure within military petroleum pipelines.

(2) Turnaround time. Once item is installed within the pipeline system, the time required for service and checkout is negligible.

(3) Reaction time. Not to exceed 1.5 seconds. The design will permit a reaction time not to exceed the critical closing time with respect to the surge pressure in each system.

(4) **Mission reliability.** The minimum acceptable reliability is 95 percent probability of operating 30 days without failure in intermediate zones for all missions.

(5) **Combat-ready rate.** After the specified equipment reaction time, the equipment must be capable of instantaneous employment. A combat-ready rate of 99 percent is required.

(6) **Operational and maintenance environmental conditions.** This equipment will be a component of an overland military petroleum pipeline in the intermediate zone over all types of terrain. Engineer units installing equipment will have maintenance tents in the TOE.

(7) **Required service life.** The proposed equipment is required to perform for a service life of at least 5 years.

(8) **Planned utilization rate.** As given in (7) above.

d. **Planning information.**

(1) **Mean downtime allowable.** The average time for correction of failures requiring maintenance, assuming repair parts, maintenance personnel, and facilities are available, shall not exceed 1 percent.

(2) **Reliability after storage.** The equipment will be designed to meet depot storage conditions as stated in Paragraph 7.1 AR 705-15 with change 1. It will be required to have reliability of 95 percent after up to 5 years of covered storage.

3. **Supporting justification and data.**

a. The estimated RDT&E funds for completing development of proposed pressure-regulating equipment by FY 71 (4th Qtr) are \$110,000. The estimated completion dates for the development: Feasibility Study FY 68 (2Q); Engineer Design FY 69 (4Q); Engineer Test FY 70 (3Q); Service Test FY 70 (3Q); Type Classification FY 72.

b. Proposed item utilizes no materials which would not be readily available under mobilization conditions.

c. No significant impact on national production capacity is expected to result from anticipated quantity procurement.



d. The technical feasibility of these items has been demonstrated by similar equipment for civilian use. There are no known technical risks that may influence the effectiveness, cost, or delivery date of the pressure-regulating equipment.

e. The estimated cost of this equipment in quantity production cost in quantities of 50 or more will be approximately \$8,000 each.

f. The proposed equipment is a completely new item. There is no like item to compare it with.

g. Enlisted personnel of any grade can be trained in a very short period of time to install the pressure-regulating equipment at a location determined by design of pipeline. Unit having the mission of laying the pipeline will locate the position of the equipment in the design of the pipeline system. Once the equipment is installed, it will be completely automatic in its operation. Human engineering characteristics shall be considered in terms of the intellectual and physical capabilities of the intended installation and maintenance personnel, and will include but not be limited to consideration of the following:

- (1) Safety and simplification of installation and maintenance.
- (2) Human space requirements for maintenance and servicing accessibility.

h. The proposed equipment will be a class IV item of issue and it is presently estimated that upon completion of standardization, 46 of this type of pressure-regulating equipment will be required as initial stock level. Requirement for each size line is as follows:

<u>Size Line</u>	<u>Type Line</u>	<u>Number Required</u>
6-in.	Coupled	6
8-in.	Coupled	15
12-in.	Coupled	5
8-in.	Welded	15
12-in.	Welded	5
Total		46

i. The estimated repair costs, including initial and annual cost, will be approximately 1 percent of purchase cost.

j. No conflicts with other projects anticipated in the use of manpower or facilities.

k. The British Army has submitted an informal comment of interest but does not wish to participate in development at present. The Canadian Army has submitted an informal comment of no interest and the Australian Army has submitted an informal comment of no requirement.

l. There is no like equipment for comparison within the British and Canadian Armies or Mutual Weapons Development Program countries.

m. The pressure-regulating equipment will have minimum overall dimensions and weight consistent with other requirements and be capable of air transport in Phase III of airborne operations.

4. Recommended priority. Recommend that this item be Priority III. Military pipelines must have the design flexibility to permit adaptability in the most rugged terrain conditions. One component required is the proposed pressure-regulating equipment.

5. Maintenance concept. The pressure-regulating equipment shall:

a. (Essential) Be designed to include all ease-of-maintenance features which are consistent with performance and reliability.

b. (Essential) Maximum use shall be made of the concept of maintenance and repair by modular replacement of assemblies of subassemblies.

c. (Essential) Simplicity in design so that skills and knowledge required to conform maintenance do not exceed the skill level of MOS 63E20, Quartermaster Heavy Equipment Repairman.

d. (Essential) Test and checkout methodology. No special test equipment other than pressure gages will be required.

(1) Allowable time for diagnosing failures will be such that 95 percent of the diagnoses will be accomplished as follows:

(a) Organizational maintenance—30 minutes.

(b) Direct support maintenance—2 hours.

(2) Allowable time for making repairs and testing for corrective action will be such that 95 percent of the activities will be accomplished as follows:

(a) Organizational maintenance—2 hours.

(b) Direct support maintenance—4 hours.

e. (Essential) Be designed with go-no-go built-in checking devices wherever practical.

6. Background information.

a. References:

(1) CDOG subparagraph number 1610(b)(6).

(2) Technical Report 1639-TR, subject, "Pressure Regulation in Long Downhill Sections of a Military Pipeline," USAERDL, dated 13 June 1960.

(3) Military Pipeline Study, USA Engineer School, May 1961.

b. Training considerations. Training in the operational use of this equipment will be the responsibility of the major quartermaster units that operate the pipeline system. Major engineer units that have responsibility to install and maintain pipeline system will conduct training on this equipment. Operating and installation manuals must be provided with the pressure-regulating equipment.

c. Related materiel. All components of 6-, 8-, and 12-in. coupled or welded pipeline system. These components are listed within the Engineer Functional Component System (EFCS).

d. Additional comments.

(1) Authority to conduct R&D is granted in Task Card, dated 17 June 1960, Project No. 1D643324D59206.

(2) USAERDL conducted engineer test on the Grove Flexflo Expandable Tube Relief Valve, Model 888. The test revealed that the Grove Flexflo Valve does not meet current established military requirements for pressure regulation in tactical-support type military pipeline systems.

e. Priority of characteristics.

- (1) Performance.
- (2) Reliability.
- (3) Safety.
- (4) Durability.
- (5) Simplicity of maintenance.
- (6) Weight.

**(7) Transportability.**

f. Every effort will be made to design desired reliability characteristics into the pressure-regulating equipment to minimize quantity of later product improvement actions required as a result of laboratory tests or field complaints. A sufficient number of competitive tests will be conducted to provide necessary reliability data and to verify that the pressure-regulating equipment meets reliability standards within the required confidence level. Reliability will be achieved through simplification of design, by keeping number of components to a minimum, by critical selection of materials, and by use of performance-proven fabrication methods.

g. If, during the development phase, it appears to the developing agency that the characteristics listed herein require the incorporation of certain impracticable features and/or unnecessarily expensive and complicated components or devices, costly manufacturing methods or processes, critical materials or restrictive specifications which will prove excessively expensive or serve as a detriment to the military value of the unit, such matters shall be brought to the immediate attention of the Chief of Research and Development of the Army, and Headquarters, U. S. Army Combat Developments Command, for consideration before incorporation into a final design.

h. This development requirement is identified as USACDC Action Control No. 6820 and supports the following:

- |                          |  |
|--------------------------|--|
| (1) Army concept program | Army 75  |
| (2) Army mission         | <ol style="list-style-type: none"><li>1. High-intensity Warfare</li><li>2. Mid-intensity Warfare</li><li>3. Low-intensity, Type I</li><li>4. Low-intensity, Type II</li><li>6. Military aid to U. S. civil authorities</li><li>7. Complementing of allied land-power</li></ol> |
| (3) Phase                | Materiel   |
| (4) Functional area      | Service support  |

## **APPENDIX D**

### **PORTABLE PRESSURE-REGULATING SYSTEMS FOR CRITICAL DOWNHILL SECTIONS OF 6-, 8-, AND 12-INCH MILITARY PETROLEUM FUEL PIPELINES**

#### **PURCHASE DESCRIPTION**

##### **1. SCOPE.**

1.1 This purchase description covers the performance, design, and testing requirements for a portable pressure-regulating system or family of systems necessary to regulate pipeline pressures in downhill sections of 6-, 8-, and 12-in. coupled and welded military petroleum fuel pipelines. All elements composing this equipment will conform with the requirements delineated herein.

##### **2. APPLICABLE DOCUMENTS.**

2.1 The following documents of the issue in effect on date of invitation for bids or request for proposal form a part of this description to the extent specified herein.

##### **SPECIFICATIONS:**

MIL-T-425 P	Tube, Steel: Pipeline Section; with Grooved Nipple Welded on Each End
MIL-C-45662	Calibration System Requirements
MIL-T-704	Treatment and Painting of Material
MIL-C-0387	Coupling, Clamp, Pipe: With Bolt and Synthetic Rubber Gasket, for Grooved-End Pipe and Tube
MIL-P-10388	Pipe Fittings: One or More Ends Grooved
MIL-P-11087	Pipe, Steel: Grooved, Threaded, or Plain Ends
MIL-P-14351 B (ME)	Pipeline Barrel, Cleaner Trap, Incoming and Outgoing

**MIL-V-13803 B (MO)**

**Valve, Gate: Double-Disk, Cast Iron or Steel**

**MIL-F-5509**

**Fittings, Flared Tube, Fluid Connection**

**MIL-P-514**

**Plates; Identification, Transportation – Data, and Blank**

**STANDARDS:**

**FED-STD-No. 595**

**Colors**

**MIL-STD-130**

**Identification Marking of U. S. Military Property**

**REGULATIONS:**

**Army Regulation 705-15**

**2.2 Other Publications.** The following documents form a part of this purchase description to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

**AMERICAN STANDARDS ASSOCIATION:**

**American Standards B16.5 1957**

**3. REQUIREMENTS.**

The portable pressure-regulating systems' requirements specified herein are based on the equipment being used on a continuous or intermittent basis in all areas of the world where military petroleum pipelines could be deployed. Such operations will include around-the-clock and all-weather use without protection from the elements.

**3.1 Performance and Design Requirements.**

**3.1.1** The portable pressure-regulating systems specified herein will be used to control pressures in military petroleum fuel pipelines constructed on critical downhill slopes. The pressure-regulating systems will operate to prevent overpressurization of pipelines and maintain packed multiproduct pipelines during operating or shutdown conditions. The pressure-regulating systems will function to prevent overpressurization of pipelines due to pressure surges which may be caused by opening and closing block valves, starting

and stopping pumps, and fuel expansion in a closed line.

3.1.2 The portable pressure-regulating systems will be required to operate over a range of flow and pressure conditions for different pipe sizes and types of pipeline construction as listed below:

Size & Type of Pipe	Type of Line Construction	Normal Flow <sup>4</sup> (GPM)	Emergency Flow <sup>5</sup> (GPM)	Pipe Pressure <sup>6</sup> Limits (psi)
6-in. <sup>1</sup> tubing	Grooved <sup>2</sup> Coupled	550	700	600
8-in. <sup>1</sup> tubing	Grooved <sup>2</sup> Coupled	950	1210	500
12-in. <sup>1</sup> tubing	Grooved <sup>2</sup> Coupled	5000	7970	400
8-in. <sup>3</sup> pipe	Welded	1100	N/A	1340
12-in. <sup>3</sup> pipe	Welded	2600	N/A	1140

<sup>1</sup>MIL-T-425      Tube, steel: Pipeline section; with grooved nipple welded on each end

<sup>2</sup>MIL-C-10387      Coupling, clamp, pipe; with bolts and synthetic rubber gasket, for grooved-end pipe and tube

<sup>3</sup>MIL-P-11087      Pipe, steel: Grooved, threaded, or plain end

<sup>4</sup>Normal flow, in gallons per minute, is the normal military design capacity for the particular line size and type of construction. Pipeline design flow rate is based on gasoline of 0.725 specific gravity and kinematic viscosity of 0.62 centistokes at 60° F.

<sup>5</sup>Emergency flow, in gallons per minute, is a maximum operable condition which may be attained in a military pipeline for relatively short operating periods. This flow is also based on gasoline at 60° F. The design of the regulating systems, to the extent feasible and efficient, will result in minimum pressure losses through the regulating systems at the emergency flows listed.

<sup>6</sup>Pipe pressure limits (psi) are the allowable pipeline pressures at the inlet to the upstream side of the pressure-regulating systems. The pressures specified indicate the maximum spacing between pressure-regulating stations or locations of the pressure-regulating systems in a military pipeline, as a result of considering the dynamic flow

and static conditions of the pipeline plus the minimum downstream pressure as described in Paragraph 3.1.3.

3.1.3 The portable pressure-regulating systems will operate to control the downstream pressure at a minimum pressure which is sufficient to retain efficient and reliable operation of the pressure-regulating system. The pressure-regulating systems will function to maintain the minimum downstream pressure irrespective of flow rate or upstream pressure during either pipeline operating or shutdown conditions. The pressure-regulating systems are required to be adjustable in that the minimum downstream controlled pressure can be increased to a maximum pressure approaching the pipe pressure limits specified in Paragraph 3.1.2 by hand adjustment to the regulating equipment.

3.1.4 The portable pressure-regulating systems will provide operation to shut down pipeline flow in the event of a downstream line break. Closeoff rate of pipeline flow will be such as to contain pressure surges within acceptable limits. The pressure-regulating equipment operating under the conditions specified in this paragraph will be provided with manual reset capability.

3.1.5 The portable pressure-regulating systems will operate to prevent upstream pressures from exceeding 110 percent of the pipe pressure limits listed in Paragraph 3.1.2. This operation is primary protection for each upstream pipeline section during shutdown conditions and will pass product from the upstream pipeline to the downstream pipeline.

3.1.6 The portable pressure-regulating systems will provide additional pipeline upstream pressure protection with a relief valve set to relieve at 100 psi above the pipe pressure limits specified in Paragraph 3.1.2. The intent of a safety relief valve is to prevent pipeline overpressurization due to human error or other circumstances whereby block valves are closed. Also, the relief valve will protect the pipeline from pressure surges encountered during normal and emergency operating conditions. The relief valve will function to prevent pipeline overpressurization due to fluid expansion in a closed system. The relief valve will discharge through a hose to a collapsible fuel tank to contain any fuel passed by the relief valve. The hose and collapsible tank are mentioned here for reference and are not to be furnished under this contract.

3.1.7 The design operating point for the portable pressure-regulating systems shall be based on regular motor gasoline with a specific gravity of 0.725 and kinematic viscosity of 0.62 centistoke at 60°F. This design operating point is consistent with the design operating point used for the design of military pipeline systems. The range of operating temperatures that the pressure-regulating systems must function over is from -40°F to +145°F (see Paragraph 3.1.9).



**3.1.8 The design of the portable pressure-regulating systems shall be based on controlling military petroleum fuels as follows:**

- a. Aviation gasoline—grades 80/87, 100/130, 115/145.
- b. Motor gasoline—regular and premium.
- c. JP-4.
- d. Kerosene.
- e. Diesel—grades DF-A, DF-1, DF-2.

**3.1.9 The portable pressure-regulating systems shall be designed for installation and operation in climatic conditions as defined in Paragraphs 7a, b, and c of Army Regulation 705-15, with Change 1, "Operations of Material Under Extreme Conditions of Environment."**

**3.1.10 The portable pressure-regulating systems will operate unattended and without an external power source. The equipment must operate solely on pipeline hydraulic pressure and be self-regulated. The pressure-regulating systems must function during conditions as follows:**

- a. Pipeline system startup.
- b. Pipeline system shutdown.
- c. Normal flow.
- d. Emergency flow.
- e. Excess flow (line break)
- f. Shutdown (static).

**3.1.11 The portable pressure-regulating systems shall be designed for portability, versatility, and interchangeability of equipment to limit the number of systems and different pieces of equipment to a minimum and still maintain efficient operation of the equipment. Where applicable, modular construction consisting of self-contained subsystems are to be used to cover the range of pipe sizes, flow rates, and pressures of the various pipeline systems listed in Paragraph 3.1.2.**

**3.1.12 The portable pressure-regulating systems shall be designed for field assembly of the system from modular components or sections of equipment considering the difficulties in field handling heavy equipment. The heaviest module or section of the system shall not exceed 4000 lb and be compatible for handling with the Army rough-terrain forklift truck. Modules or sections of equipment of the pressure-regulating systems shall be suitable for transport by vehicles available within the Type Field Army.**

**3.1.13 The envelope size and weight limitations on any one assembled portable pressure-regulating system shall be confined within the following limits:**

- a. Height—48 in.
- b. Width—108 in.
- c. Length—120 in.
- d. Weight— 10,000 lb.

The intent of the height restriction is to restrict the silhouette of the system as much as possible consistent with efficient design. The width, length, and weight restrictions will permit transport of the assembled system within a cargo aircraft.

3.1.14 The portable pressure-regulating systems shall be designed for air-transportability by helicopter, with the pressure-regulating system in the fully assembled condition and suspended by slings from the aircraft.

3.1.15 The portable pressure-regulating systems shall be designed with the appropriate interfaces for connection to the pipeline. Types of interface will be consistent with the type of line construction specified in Paragraph 3.1.2 herein. Regulating systems for use in victaulic coupled pipelines will be designed with grooved nipples consistent and equal to the grooved nipple designs specified in MIL-T-425 P, Tube, Steel; Pipeline Section; With Grooved Nipple Welded on Each End. Pressure-regulating systems designed for the welded pipeline construction specified in Paragraph 3.1.2 will be designed with appropriate bolt flanges conforming to American Standards Association, American Standards B 16.5 1957, Steel Pipe Flanges, Class 600.

3.1.16 The portable pressure-regulating systems will be designed to permit passage of pipeline scrapers or incorporate provisions for receiving and sending scrapers. Incoming and outgoing cleaner trap pipeline barrels specified in the design of the pressure-regulating systems will conform to MIL-P-14351 B (ME), Pipeline Barrel, Cleaner Trap, Incoming and Outgoing.

3.1.17 Valves used in the design of the pressure-regulating systems shall conform to MIL-V-13803 B (MO), Valve, Gate: Double-Disk, Cast Iron or Steel.

3.1.18 Control lines and fittings used in the design of the pressure-regulating systems shall conform to MIL-F-5509, Fittings, Flared Tube, Fluid Connection.

3.1.19 Grooved-type pipe fittings used in the design of the pressure-regulating systems shall conform to MIL-P-10388, Pipe Fittings, Malleable Iron, Steel, or Aluminum-Alloy, Grooved Type.

3.1.20 Maximum utilization shall be made of materials that will not be considered critical during national emergencies and materials that are light in weight to facilitate handling and air-transportability.

**3.1.21** Except for expendable interior components, the pressure-regulating systems shall have an effective life of at least 5 years of continuous or intermittent service under the environmental requirements of Paragraph 3.1.9 herein.

**3.1.22** The reliability of the pressure-regulating systems shall be at least 95 percent probability of operating 30 days without failure in intermediate zones for all missions.

**3.1.23** The pressure-regulating systems will be designed to meet depot storage conditions as stated in Paragraph 7.1 of AR 705-15 with Change 1.

**3.1.24** The pressure-regulating systems shall be designed for a service life of at least 5 years.

**3.1.25** Human engineering characteristics shall be considered in the design of the pressure-regulating systems in terms of the intellectual and physical capabilities of the intended installation and maintenance personnel, and will include, but not be limited to, consideration of the following:

- a.** Safety and simplification of installation and maintenance.
- b.** Human space requirements for installation, adjusting, maintenance, and servicing accessibility.

**3.1.26** The design of the pressure-regulating systems shall allow for maximum use of maintenance and repair by modular replacement of assemblies or subassemblies. No special test equipment shall be required during installation or checkout other than pressure gages.

**3.1.27** Reliability of the pressure-regulating systems will be achieved through simplification of design, by keeping the number of components to a minimum, by selection of materials and components, and by use of performance-proven fabrication methods and components.

**3.1.28** Lifting Attachments. The portable pressure-regulating systems will be provided with permanently affixed attachments that enable the assembled system to be lifted in its normal operating position. Each attachment shall withstand, without damage to any part of the system, 2.5 times the resulting vectorial force imposed when the system is suspended by the lifting attachments. Attachments for multiple slings shall be located so that: (a) Slings will converge at not more than 19 ft above the lowest extremity of the system; and (b) not less than 1-in. clearance will be maintained between the slings and the system. The inside diameter of the attachment eye shall be not less than 3 in. Lifting attachments may also be used as tiedown attachments when such attachments meet the requirements specified herein.

STANDARD FORM 30, JULY 1965 GENERAL SERVICES ADMINISTRATION REG. PROC. REG. (41 CFR) 1-16.101		AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT		PAGE 1 OF 3
1. AMENDMENT/MODIFICATION NO. <b>POOL</b>		2. EFFECTIVE DATE <b>70 APR 21</b>		3. REQUISITION/PURCHASE REQUEST NO. <b>70-E-1105</b>
5. ISSUED BY <b>S. Army Mobility Equipment Research and Development Center R&amp;D Procurement Office Fort Belvoir, Virginia 22060</b>		6. ADMINISTERED BY (If other than block 5) <b>Chief, DCASO Oklahoma City 621 N. Robinson Oklahoma City, Oklahoma 73102</b>		
7. CONTRACTOR AND ADDRESS <b>Williams Brothers Company National Bank of Tulsa Building Tulsa, Oklahoma 74103</b>		8. AMENDMENT OF SOLICITATION NO.  DATED _____ (See block 9)  <input checked="" type="checkbox"/> MODIFICATION OF CONTRACT/ORDER NO. <b>DAAK02-70-C-0119</b> DATED <b>69 OCT 30</b> (See block 11)		
9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS <input type="checkbox"/> The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of offers: <input type="checkbox"/> is extended, <input type="checkbox"/> is not extended. Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods: (a) By signing and returning _____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.				
N/A				
11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS (a) <input type="checkbox"/> This Change Order is issued pursuant to _____ The Changes set forth in block 12 are made to the above numbered contract/order. (b) <input type="checkbox"/> The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12. <input checked="" type="checkbox"/> This Supplemental Agreement is entered into pursuant to authority of <b>10 U.S.C. 2304(a)(11)</b> It modifies the above numbered contract as set forth in block 12.				
<div style="display: flex; justify-content: space-between;"> <div style="width: 80%;"> <p style="margin-bottom: 10px;">12. DESCRIPTION OF AMENDMENT/MODIFICATION</p> <p>The following is deleted from paragraph 3.1.2. of the Purchase Description: "12-inch tubing, grooved coupled, 5000 gpm normal flow, 7980 gpm emergency flow, pipe pressure limits 400 psi".</p> <p>The last sentence of paragraph 3.1.15 of the Purchase Description is changed to read: "Pressure-regulating systems designed for welded pipeline construction specified in para 3.1.2 will be designed for use in vitaulic coupled pipelines."</p> <p>The first sentence of paragraph 3.1.5 of the Purchase Description is changed to read: "The portable pressure-regulating systems will operate to prevent upstream pressures from exceeding the following values for each type and pipe size:</p> </div> <div style="width: 15%; text-align: center; font-weight: bold; writing-mode: vertical-rl; transform: rotate(180deg);">NOT REPRODUCIBLE</div> </div>				
Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.				
13. <input type="checkbox"/> CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT <span style="float: right;">Orig &amp; 2</span> <input checked="" type="checkbox"/> CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN _____ COPIES TO ISSUING OFFICE				
15. NAME AND TITLE OF SIGNER (Type or print) <b>Morgan A. Greenwood Sr. Vice President</b>		16. DATE SIGNED <b>4-16-70</b>		17. NAME OF CONTRACTING OFFICER (Type or print) <b>ROGER L. SANDALL</b>
18. NAME OF CONTRACTING OFFICER (Type or print) <b>ROGER L. SANDALL</b>		19. DATE SIGNED <b>70 APR 21</b>		

Page No. 2  
Contract No. DAAK02-70-C-0119  
Modification No. P001  
WILLIAMS BROTHERS COMPANY

<u>Pipe Size &amp; Type</u>	<u>Set Point for Back-Pressure Valve</u>
6-in. tubing	660 psi
8-in. tubing	550 psi
12-in. tubing	440 psi
8-in. welded pipe	1390 psi
12-in. welded pipe	1190 psi

The first sentence of Paragraph 3.1.6 of the Purchase Description is changed to read: "The portable pressure-regulating systems will provide additional pipeline upstream pressure protection with a relief valve to be installed immediately upstream of the two gate valves in the scraper trap assembly and set to relieve at 100 psi above the pipeline pressure limits specified in Paragraph 3.1.2."

As a result of the foregoing modification, there will be no change in the total estimated contract consideration.

## APPENDIX E

### PROPOSED PROCEDURE FOR LOCATING PRESSURE-REGULATING STATION

**Overpressure Checks.** Due to differences in elevation and the location of pumping stations, it is possible for pressures to occur in the line greater than the pipe can withstand. Where this occurs the pipe must be protected to withstand the pressure.

Two separate conditions must be checked: Static and dynamic.

#### (1) Static Pressure Check

Consider sample profile, Fig. E-1.

It can be seen that at miles 33.5 and 45, a high pressure will occur due to the pressure of the column of fluid extending from the top of the hill at mile 25 to the valleys. To find if the column of fluid creates enough pressure to burst the military light-weight tubing the following graphical analysis is performed:

- (a) The safe working pressure (SWP) (assume 8-in. tubing) is 507 psi.
- (b) Convert this pressure to feet of head of the design fuel.  
$$\text{Head} = \frac{2.31 \times \text{SWP}}{\text{Sp. Gr.}}$$
- (c) Measure down from the top of the hill the number of feet obtained in (b).
- (d) Draw a horizontal line extending downstream from the point obtained in (c).
- (e) Wherever the profile drops below this line, that section of pipe is overpressurized.

Figure E-2 shows the graphical analysis for the static pressure check.

$$\text{SWP} = 507$$

$$\text{Head} = 2.31 \times 507 \text{ (Assume JP-5 fuel at } 0^{\circ} \text{ F)}$$

$$\text{Head} = 1430 \text{ ft}$$

From Fig. E-2, it can be seen that the section of pipeline from mile 30.5 to mile 36.5 and the section from mile 43.5 to mile 46 must be protected from overpressurization.

(2) Dynamic Pressure Check.

The dynamic pressure check takes into account the effect of the pump pressure and the friction loss when the fuel is flowing.

The graphical check consists of the following steps:

(a) Find total pressure at the outlet of the first pumping station upstream from the valley. This would be station No. 3 in Fig. E-3. The total pressure will be the sum of the pumping station pressure, the priming pressure, and any excess pressure from the feeder pumps. Assume this to be 1100 ft.

(b) Convert this pressure to feet of head of the design fuel.

$$H(\text{Total}) = \frac{2.31 \times \text{Total Pressure}}{\text{Sp. Gr.}}$$

(c) Measure up from the pumping station location this number of feet and mark the resulting point. See Fig. E-4.

(d) Determine SWP of the tubing being used. Convert this to feet of head of the design fuel:  $H \text{ safe} = \frac{2.31 \times \text{SWP}}{\text{Sp. Gr.}} = 1430 \text{ ft}$

(e) Measure down from the point obtained in (c) above, the feet of safe working head obtained in (d).

(f) From the resulting point draw a line extending downstream and having the same slope as the hypotenuse of the hydraulic gradient triangle. Call this line A. See Fig. E-5.

(g) Line A intersects the profile; therefore the safe working pressure of the tubing between 29.5 and 35 miles must be protected from overpressurization under dynamic conditions.

Because of static and dynamic overpressures the section of pipe from mile 29.5 to 36.5 and the section of pipe from mile 43.5 to 46 have to be protected.

(3) The hydraulic gradient is obtained by constructing a hydraulic gradient triangle. This triangle is constructed to the same scale as the profile. Its altitude (ordinate) represents the available feet of head at discharge of the station. This is found by multiplying the design output pressure of the station by 2.31 and dividing by the specific gravity of the design fuel

$$\text{Head} = \frac{\text{Station Pressure}}{\text{Sp. Gr.}}$$

Its base (abscissa) represents the distance in miles that the discharge head can move fluid against the friction in the pipeline at the normal design rate of flow on level terrain. This is found by dividing the available head by the friction loss of the pipe in feet of head per mile. The hypotenuse of this triangle is the hydraulic gradient. This gradient represents the rate of head loss due to the friction for a specific size of pipe, carrying a specific fluid, at a specific rate of flow. If any factor—pipe size, liquid, or rate of flow—is changed, a new triangle must be constructed.



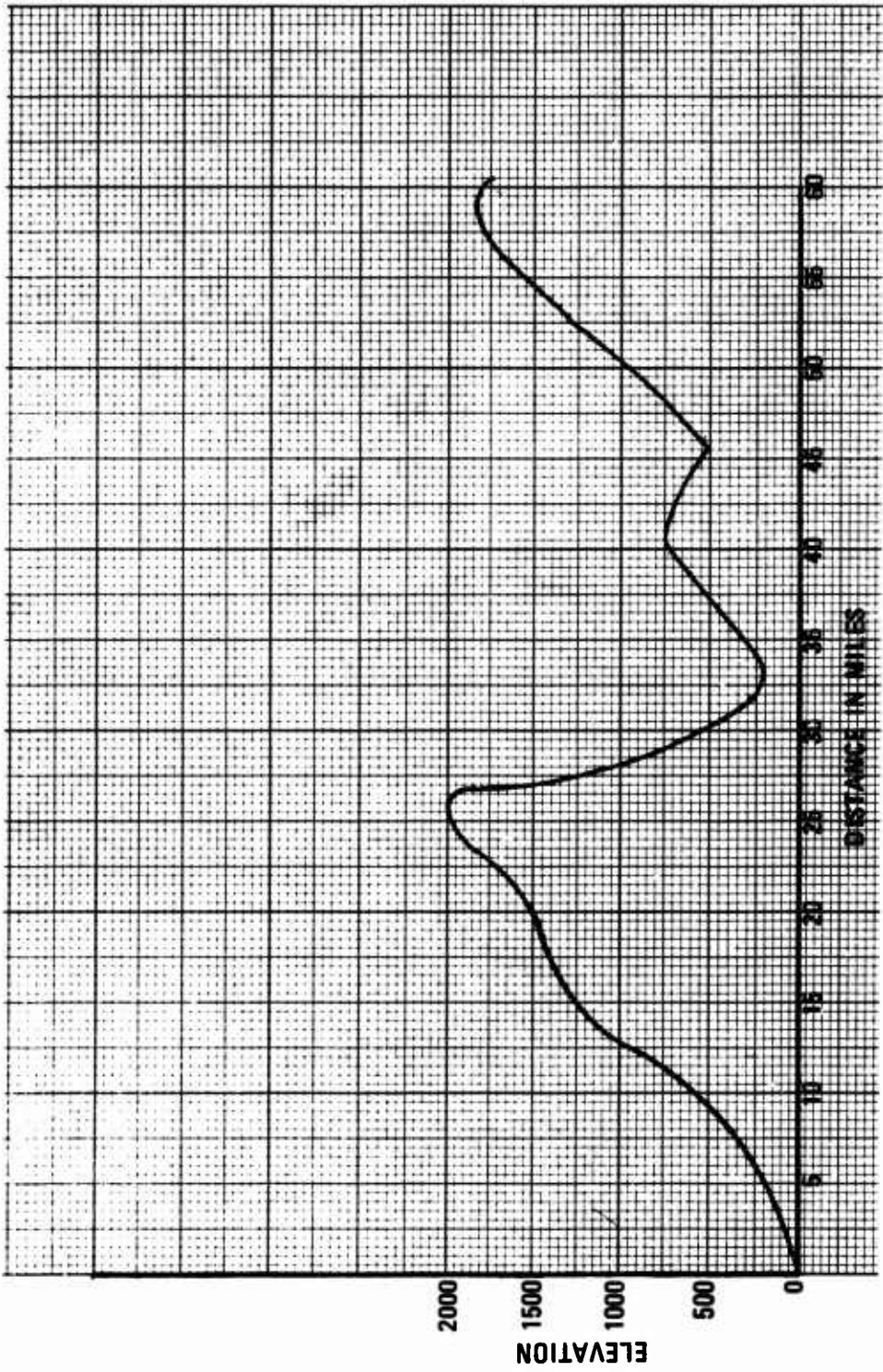


Fig. E-1. Sample profile.

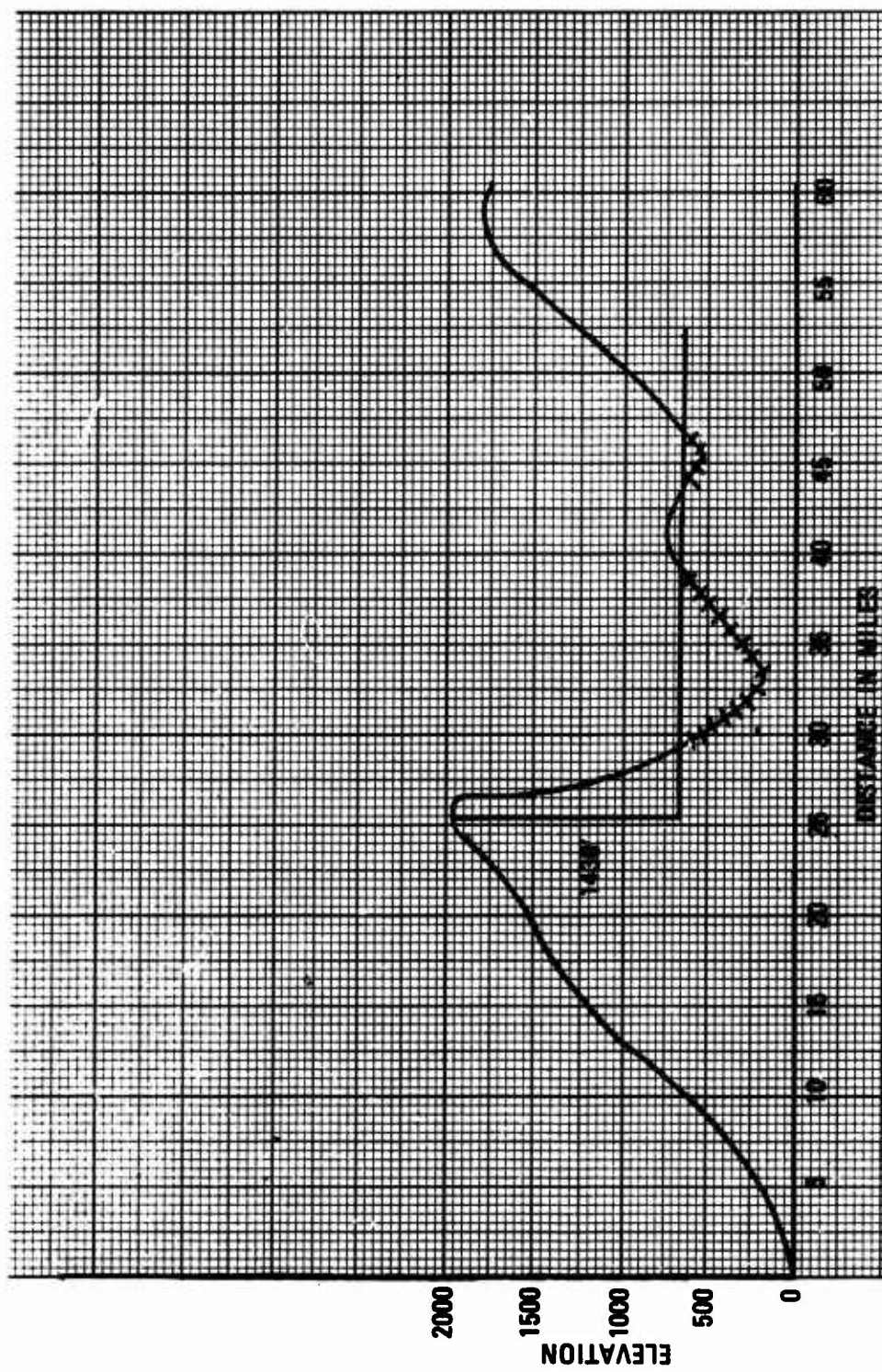


Fig. E-2. Static overpressure check.

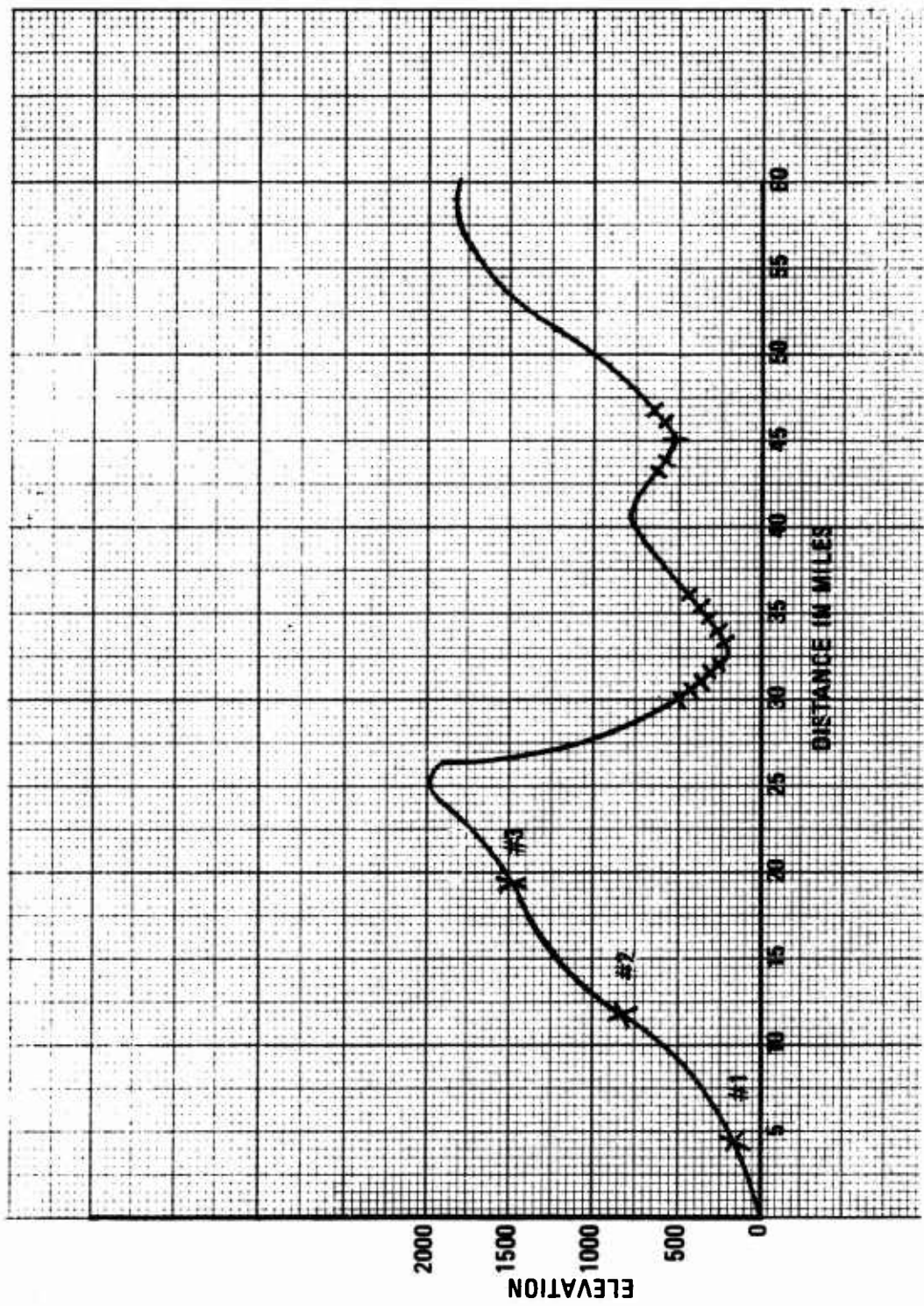
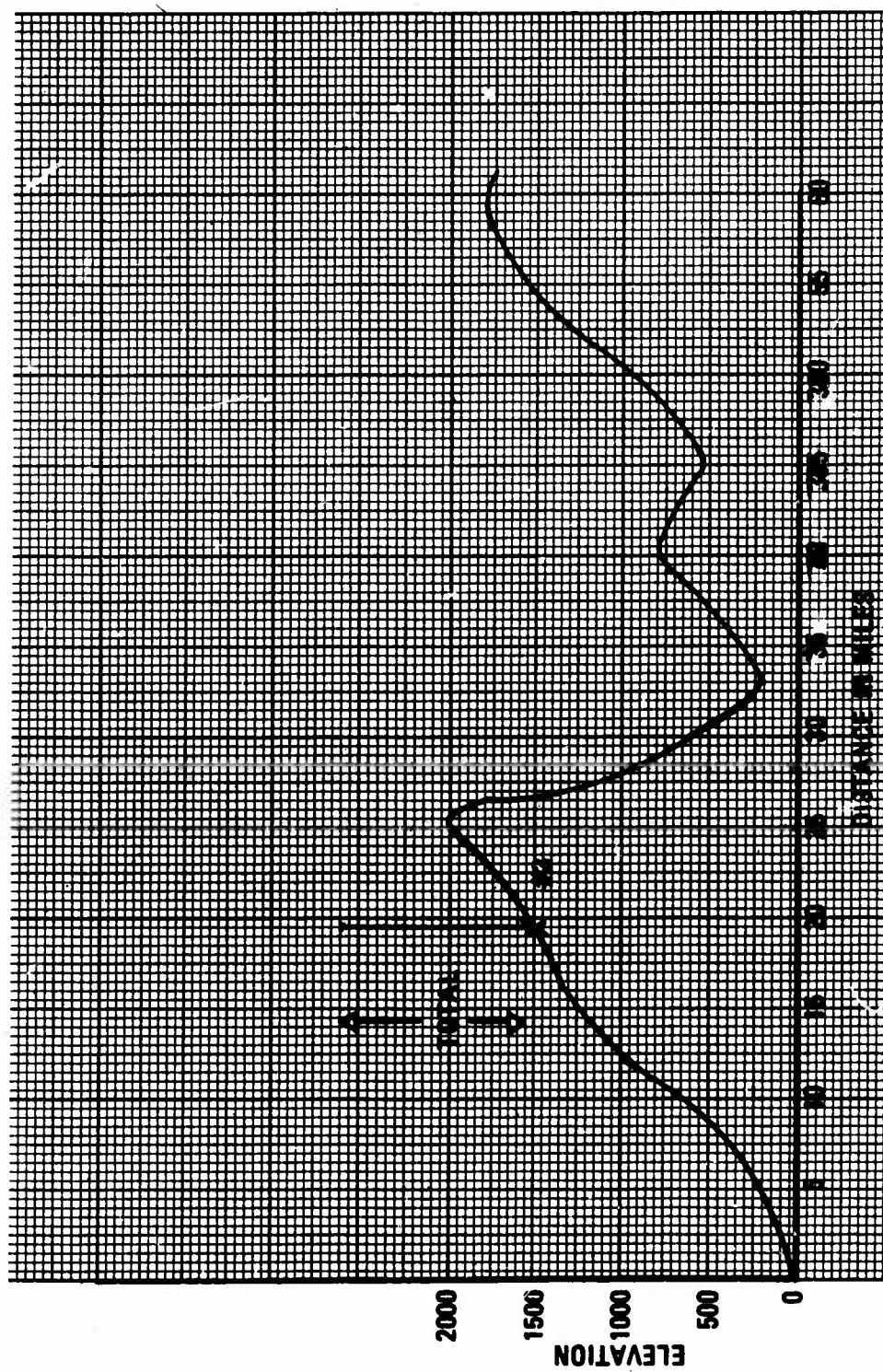


Fig. E-3. Profile with pumping stations 1, 2, and 3.



**Fig. E-4. Total head at Station No. 3.**



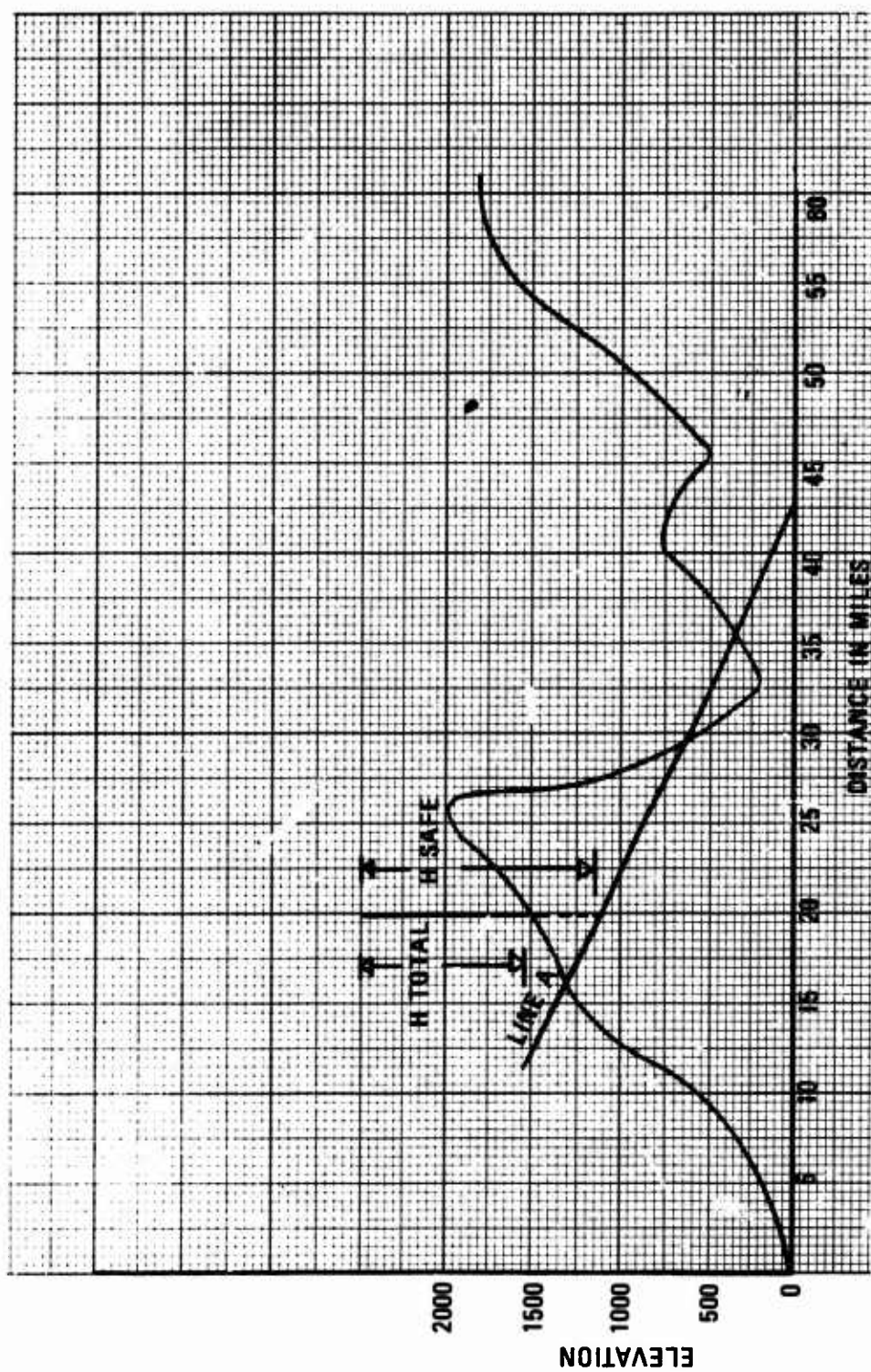


Fig. E-5. Locating pressure-regulating station.

## **APPENDIX F**

### **PROPOSED WHITTIER-ANCHORAGE PIPELINE**

#### **Proposed:**

An 8-in. multiple products pipeline from Whittier, Alaska, over Indian Mountain to Anchorage, Alaska. Pump stations at Whittier and Indian Mountain.

Pipeline to transport JP4, fuel oil, diesel, aviation and motor gasolines.

Capacity to be predicated on ability to handle JP4 at low temperatures, other products to fall into their corresponding throughputs when line is designed for that JP4 capacity.

If possible, line is to be capable of expanded capacity by addition of pumps at the two designated pump stations at Whittier and on Indian Mountain.

Pipe to be grade A .227-in. wall thickness and intended to operate at not over 1440 psi.

Section of line through populated area from Campbell Creek to Anchorage to be protected from high pressures by a reducing-valve station at Campbell Creek to limit pressures out of Campbell Creek valve station to a maximum 600 psi.

Engineering done by Brown and Root and original assignment finished as of date of this report.

Consultant S. S. Smith employed by Corps of Engineers to review work of Brown and Root and "... to make the line a practical operation ..."

The report within embodies the review by consultant together with such comment and recommendations as seem pertinent to the problem.

In view of very limited phone instructions by Mr. George, Chief Engineer at Anchorage, to the consultant, there may be omissions or additions not contemplated in instructions but assumed by consultant. If this is true, it is hoped that the report does not transgress instruction too far.

In the preparation of this report, it is assumed that readers are familiar with the project, its topography, place names, and some of its hydraulic problems, it being assumed that Brown and Root's previous communications are available.

At the outset of this report, it must be stated that the engineering which has been performed by Brown and Root seems comprehensive and complete. While it has not been examined in bolt and nut detail, it is immediately apparent that there can be small merit in making a minute examination of this work, since even a cursory examination shows it to have been competent and complete; design extremely well adapted to the requirements delineated by the Army.

Thus this report should be considered as a supplement to the work of Brown and Root, whose personnel have already fully met the criteria laid down in their contract if their assignment be fully understood.

It would appear then that the services of a consultant were deemed desirable to augment the scope of planning which was originated by the Army before the employment of Brown and Root, and this is the light in which the within report is undertaken.

It is immediately apparent that the gradients of this proposed pipeline pose problems that are not easy to solve.

A level or uphill line can be operated or shut down while maintaining a solid column of fluid under pressure. A line on rolling terrain will usually not be difficult to operate because any existing static pressures will be washed out in flow friction.

In the present situation, the flow friction of the line is only a small proportion of the pressures available to provide flow over the downhill section of the line.

There are only three basic methods of controlling this present type of line. Broadly classified, they are:

1. Back pressure the line to sufficient pressure to hold a tight line or solid liquid column to the top of grade when the line contains the heaviest product it will contain. The advantage of this method is that the line is always full of fluid (neglecting thermal contraction when not operating). The disadvantages are that back pressures held at a low point add the pressure of friction loss in flow to the pressure required to pump over the high point of the grade and, therefore, require that the fluid be pumped down the hill and thus continuously waste horsepower.

A further disadvantage is that back-pressure valves with high-pressure drops and consequent high velocities are difficult, if not impossible, to keep tight, and if not

kept tight, fail their function during shutdown.

2. Provide a flow restriction in the form of an orifice, a flow bean, or a length of small-diameter pipe equivalent to many miles of the main-line pipe size.

The advantages of the small-diameter-pipe method are that it is permanent and does not change its characteristics nor does it require excess horsepower, if it can be properly controlled to match flow rates.

The last qualification naturally delineates the disadvantages of the flow restriction in that it may be difficult to design to fit widely varying rates of flow and changes of product.

3. Flow rate control of output volumes to match input volumes, either by automation or by observation and manual settings.

The advantages are fairly obvious if this method would work, but in practice it will be found that the compressibilities of fluid, its changes of volume with temperature, and the difficulty of maintaining constant data communication and accurate measurement between line input and line output locations rule this method out as impractical.

There can be combinations of method 2 which can be made practical and workable, avoiding the disadvantages of either method used by itself.

It is the purpose of this report to recommend additions to the engineering which Brown and Root were instructed to perform, the purpose being to make the pipeline a more realistically operable line in view of its inherent complexities.

From the foregoing, it is readily apparent that there is a possible approach to valid solutions of the broad hydraulics of this pipeline if method 2 can be fitted to the requirements of the system by installing resistors to flow which can be varied in function. To apply any such combination, the design parameters must be defined and the basic engineering "numbers" must be discussed from a common understanding. As it is helpful to break up any complex problem into a number of more simple sections, that effort has been made in this analysis.

The first is to construct flow curves for the products which will be transported through the main line and through restricting pipes which may conceivably be used to add to the effective length of the 8-in. line. This is done and here published in Fig. F-1.





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The second step is to prepare an analysis of operating pressures and flow rates based on Fig. F-1, the analysis assuming that there is need for the addition of the type of supplemental control which has been discussed and further assuming that the solutions offered are suitable or can be altered to be suitable.

The basis of all of these computations is that operations can and will be conducted with two, three, or four pumps in Whittier and Indian Stations. Further assumptions are made that the pumps in Whittier and Indian have approximately equal characteristics even though Whittier pumps are diesel driven at variable speed and Indian pumps are driven at constant. Since both stations have complete pressure control and, if desired, Whittier pumps may be speed controlled, this assumption should be valid.

It is also assumed that the pumps will operate essentially wide open, functioning at pump curve pressures on the product and volume rates.

Basically, then, flow rates are computed by using full-pump characteristics in both stations at about 50# Whittier suction pressure and approximately the same pressure at Summit leaving the throughputs and pressures at downgrade points of Campbell Creek and Anchorage to be derived after arriving at some flow rate to Summit.

Thus it will be seen that for each pumping condition there is a separate control problem of design to match pipe frictions to flow at Campbell Creek to protect a solid column from Summit to Campbell while still providing downstream pressure to not violate 600# stream pressures and provide flow to Anchorage and up to 275# input pressure to tanks.

All of these computations appear in Table F-I arranged by pumping condition headings and with flows defined and pressures and pressure drops shown for each heading. They also reflect the pressure differentials to be provided by an automated variable restriction at Campbell Creek.

These plates have been prepared for several reasons. Brown and Root has made its hydraulic studies, quite properly, by fitting hydraulic gradients for various products to the topography of the line, the basis being feet of head.

This is the usually accepted and generally used method of fitting the hydraulic features of a pipeline to the designed pump curves.

But the user of a pipeline, who may be completely conversant with this method, is more apt to think in terms of gage pressures which he reads from gages or recorders, and/or in terms of volume of flow which is recorded by the operating meters, and he mentally adjusts the two factors to the product he is pumping.

Table F-1. Analysis of the Flow Factors, Whittier-Anchorage 8-Inch Products Pipeline

	2 Pumps - JP4 740 Lb Pump Diff. 6.4 Lb/Mi. 15,000 B/D		3 Pumps - JP4 645 Lb Pump Diff. 16.7 Lb/Mi. 24,25,000 B/D		4 Pumps - JP4 575 Lb Pump Diff. 26 Lb/Mi. 31,000 B/D		3 Pumps - Gasoline 585 Lb Pump Diff. 15.3 Lb/Mi. 27,000 B/D		4 Pumps - Gasoline 650 Lb Pump Diff. 31.7 Lb/Mi. 27,500 B/D		6 Pumps - JP4 470 Lb Pump Diff. 36,000 B/D	
Whittier Station suction pressure		50		50		50		50		50		50
Whittier pump differential	740	790	1290		1150		1170		1300		1410	1440
Whittier Station discharge pressure		790		1380		1200		1220		1350		1440
Static differential to Indian	105	685	105	1275	105	1095	95	1125	110	1240	105	1335
Friction of flow to Indian	208	477	565	710	885	210	605	605	1080	160	1285	50
Indian suction pressure		477		710		210		605		160		50
Indian pump differential	740	1217	645	1355	1150	1360	505	1190	1300	1440	1390	1440
Indian discharge		1217		1355		1360		1190		1440		1440
Static to summit	1152	65	152	203	1152	208	1058	132	1236	204	1152	288
Friction to summit	34	31	92	111	143	65	82	50	175	29	214	74
Pressure at summit		31		111		65		50		29		74
Static head to Campbell	1139	1170	1139	1250	1139	1204	1027	1077	1220	1249	1139	1213
Friction to Campbell	70	1100	184	1066	286	918	168	909	349	900	429	786
Campbell inlet pressure		1100		1066		918		909		900		786
Adjusted differential through "pipe organ"	330	770	680	386	489	429	535	374	396			
Pipe organ outlet pressure		770				429		374		500		
Campbell reducing valve differential	170	600	0		0		0		0		186	600
Campbell outlet pressure		600										
Static head to Anchorage	108	708	108	494	1.8	537	99	473	112	612	108	708
Friction to Anchorage	63	645	168	328	260	277	150	323	300	300	382	426
Anchorage inlet pressure		645								312		426
Valve differential (flow bean)	370		53		0		48		37		151	
Valve outlet pressure		275		275				275		275		275
To 275 and or 50 Lb Reducing Valve		275				275						
50 Lb Reducing valve differential	225						225		225		50	
To terminal		50						50				

The restriction coils calculated for Campbell Creek are 700 ft + 330 ft + 1545 ft of 3 in. The 300 ft and 1545 ft coils are bypassed automatically by using the pressure differential across the 700 ft coil as the valve control index. The coils are calculated so that all three coils are working when pumping JP4 and gasoline with three pumps. Two coils operate when using JP4 with four pumps. One coil operates when pumping diesel with four pumps and in future a third valve will be

required to operate with six pumps. From the differentials generated across the pipe organ, it can be noted that it is not possible to cover desired range of flows with a valve opening at preset differential or back pressures. This is not a simple thing to demonstrate except as done above, and in Table F-1.

So it seemed quite logical to set up the tables in Table F-I which delineate the critical areas for control and in some degree suggest possible solutions for these critical areas.

The foregoing more or less defines the problem the designer faces in making this an operable line. It may be proper here to comment on several facts which, while not specifically directed to the problems at hand, are worthy of note in promoting better understanding of the whole situation.

Brown and Root's formulations for pipeline flows are the classic fundamental formulae. The writer's formulation is derived from a fundamental research into modifications of the Williams and Hazen formula which was developed to correct the deficiencies of that formula so that C factors remained constant over a range of pipe sizes and with products other than gasoline pumped in the line. This formula has been proved accurate over wide ranges of flows and products. It is stated on Fig. F-1 and results in good agreement with computations of Brown and Root in connection with these line calculations. As the various responsibilities assigned to Brown and Root and consultant are understood here, Brown and Root was commissioned to provide the mechanical design for the pump stations to meet a specific criteria of volume at 24,000 B/D when pumping JP4. It was desired that the pump station design could be expanded to perhaps 36,000 B/D by addition of standby power and pumps for emergency use. Brown and Root was not specifically charged with the responsibility for the line's ability to deliver specification products at all the flow rates possible, the basic background of this phase of the design having remained in the choice of criteria by the military.

The charge to your consultant, if properly understood, did not necessarily confine itself to the scope of Brown and Root's work, but is understood to compass the full scope of advice to the end result that the line be safely operable in the range of products handled and with control of pressure, flow, and liquid column adequate to the protection of product specifications. As to the work done by Brown and Root, it must be reiterated that it has been accomplished in complete and excellent fashion and there will be little comment bearing on their work.

It is expected that this line, which is dependent upon supplies by tanker, may be shut down for appreciable periods. It is stated and assumed that when shut down, the temperature variations may generate pressures requiring pressure relief on the line. On any properly accounted pipeline, this will involve input and output measurement of product. As designed under the set criteria requiring possible valve closure at Campbell Creek reducing valves, it has been necessary for Brown and Root to provide a high-pressure relief at Indian Station and take the drainage from that valve into the Whittier line and terminal. Comment is made here that this arrangement requires "put and take" accounting for product at Whittier. If thermal relief does occur, the line may then be

slack and contain voids when started again so that this starting problem is present. The suggestion is offered that the degree of drainage is unimportant during shutdown since it must be recognized at startup regardless. It is, however, a complication of accounting to take drainage as now contemplated at both Anchorage and Whittier. It might be much "cleaner" accounting to always charge to the line at Whittier and always credit to the line at Anchorage. This involves no change in existing engineering except to maintain a constant open line relieving the line to Anchorage tankage through a back-pressure valve at a setting which will not close the reducing valve at Campbell Creek. This procedure will obviously provide a larger drainage into Anchorage than now contemplated but has the offsetting advantages of keeping all parts of the line at levels below normal working pressure which the high-pressure relief at Indian does not do. Measurement accuracy above that available with turbine meters at low flow rates might properly be provided by installation of a small PD meter at Anchorage in the event this change of procedure is accepted.

Table F-I has been computed to show operating conditions with variable restriction at Campbell adjusted to approximate complete "tight-line" control. Startup after shutdown may be a matter of concern to operators. It need not be. Until pressure differentials come up to full flowing conditions at Campbell Creek, the greatest restriction will be in the circuit, and the line will quickly fill back to Summit and assume its normal flow rates. No violent shocks will occur as the line fills because of the small differences between "full-line" and "slack-line" rates of flow.

At this juncture, this report has deliberately avoided the crucial factors of product validity except to note in the context of Table F-I that under certain conditions of flow rate and product the flowing pressures can be made to balance out to match static heads if the restrictions at Campbell Creek and Anchorage are adjusted to specific conditions. This is not a guarantee that they will so balance, so it is mandatory that supplemental to the data presented in Table F-I some effort be made to reconcile the variations which may occur in operations to the maintenance of a tight line from the top of the mountain to Anchorage. Let it be noted here that when the line is running at any rate in any one product, this tight line is not required and can be considered of only academic interest. But the moment dispatching operations begin and the line begins to adjust itself to changing flow rates, there is no reasonable way to operate a tight line without wasting horsepower and adjusting input pressures or alternately adjusting friction of flow characteristics. Thus this problem must be faced in design and the choices left to the designer are confined to the relative merits of inefficient use of horsepower and capacity or of presenting a problem of control to the operators.

This may not be quite as bad as it sounds when so baldly started. The ideal of course is to come over the mountain with flows nicely adjusted in the uphill and downhill section so that the pressures at the Summit are about 50#. However, Summit is

remote and there is no provision for recording and transmitting pressures from that point to Whittier or Anchorage. However, Indian Station discharge pressure is higher than Summit by the static differential and pipeline friction components added to each other. It is not too difficult to work out tables which show typical static pressure and friction drops for various rates and products so that, in fact, operators at Anchorage can under any conditions estimate pressures at Summit as a function of Indian's discharge pressure. This pressure may be read out at any time over data-transmission equipment. With this method, Anchorage personnel can assume control of Summit-Anchorage conditions provided that they do not add enough back pressure at Anchorage to actuate the reducing valve at Campbell Creek. This latter effect is to be avoided because inadvertent closure of Campbell Creek may result in water hammer shocks and can easily cause high pressures and shutdowns at Indian and Whittier stations. So the permissible variations in back pressure at Anchorage will be limited to those which avoid interference with Campbell Creek's valving. If interference does occur, the drainage into Whittier is superior to the previous suggestion in this report that it always be taken into Anchorage. Therefore, the suggestion made herein should retain the features designed by Brown and Root to drain the line westward in the expectation that these features would be operative only in the case of inadvertency.

The foregoing is based on the assumptions contained in Table F-I tables of pipeline pressures, which in turn are based on the use of three different lengths of restriction coils at Campbell Creek. These three coils are shown in Fig. F-2 in schematic form and their functioning is described in Table F-II.

The proposed Campbell Creek installation described and rated in Fig. F-2 and Table F-II is intended to offer a set of conditions which reduce flow rates across the line as little as possible.

The control provided by this installation at Campbell Creek should be supplemented at Anchorage with some easily adjustable flow restriction which can be used to "trim" the Campbell Creek controls. A "flow bean" or globe type valve is suggested upstream of the reducing valves at Anchorage.

The operators who control the pipeline at Anchorage will understand that if they have a reasonable setting on their throttle flow conditions do not change on a pipeline unless the pumping conditions are changed. If they somewhat overcontrol, no damage will be done for the line will adjust itself to a higher pressure at Whittier and Indian that will slow down to its higher resistance factor.

Thus the hydraulics of this line can be designed so that while not completely automated in its functions, it is essentially so if given intelligent operation.

It is again pointed out that, any time, the flow may be overcontrolled at Anchorage. Thus a product interface can be tightened up on the downgrade or a runaway stream can be held when the pumping rates are slowed, by throttling at Anchorage. No penalty is involved in this type of overcontrol except minor losses of capacity, and overcontrol is advocated until operators can adjust coil lengths and become thoroughly familiar with the line operating characteristics.

This project should now come gradually into focus. It is possible and practicable to maintain a tight line and protect product quality. The cost of the suggested additions are a minor percentage of the project cost; and without these additions, the project leaves much to be desired from the standpoint of product quality control.

Study of Table F-I immediately indicates that the most efficient and practical operation of the line should, where possible, be confined to three pumps in JP4 and gasolines, and to four pumps in dieseline and JP4. It also becomes apparent that when one heavier product follows a lighter product some overcontrol should be exercised at Anchorage until the line delivery of the batch head is accomplished.

The more obvious operating safeguards such as pressure settings on discharge pressures, the handling of low throughput-rate starting conditions in pumps, and the tendency of pump controls to overload motors and diesels during low pressure startups have been neglected in this report, the view being that these conditions are well known to all competent pipeliners and are taken for granted here as having been foreseen and the necessary safeguards provided.

It will be understood that in the area of control and controller planning for any project, tentative pressure drops and suggested control settings are provided in the full expectation that any differences between computed settings and those found necessary to actual practice will be altered as required after the line is operating. In this project this caution is specifically directed to the pressure settings and pipe lengths shown in Fig. F-2 and Table F-II.

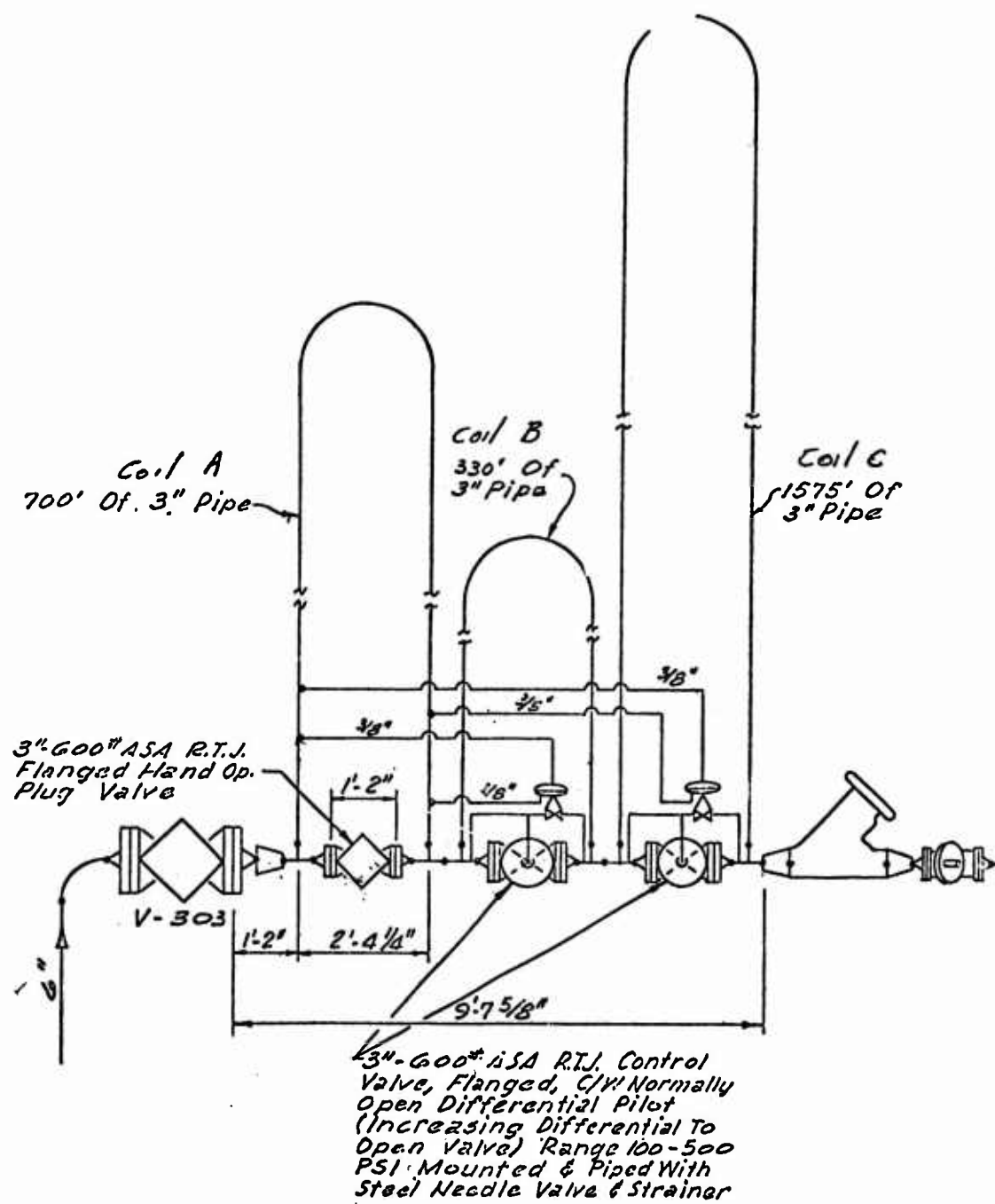


Fig. F-2. Whittier-Anchorage pipeline, schematic.



Table F-II. Design Factors Used for the “Pipe Organ”  
Recommended for Installation at Campbell Creek

		<u>Pumping Conditions</u>				
JP4	Diesel	JP4	Gasoline	JP4	JP4	
36,000	27,500	31,000	27,000	25,000	15,000	
6 Amp	4 Pps	4 Pps	3 Pps	3 Pps	2 Pps	
<u>Pressure Differentials Across Coils</u>						
Coil A						
700'	(450)*	(396)	332	146	200	NOT
Coil B						
330'	210	184	157	68	93	GOOD
	1030		(489)			
Coil C						
1545'	990	870	731	321	387	OPERATION
	2575			(535)	(680)	

\* Figures in parentheses are total differentials used.

To make the Campbell “Pipe Organ” automatic, the pressure differential across Coil A is used for control. Up to 200-210# across Coii A, both bypass valves remain closed and a total coil length of 2575 ft is used.

Above 200-210#, the valve bypassing Coil C is opened and 1030 ft of pipe remain in the total coil with the pressure differential shown.

A still further raise of differential across Coil A to 340-360# finally opens the second valve and only Coil A remains in circuit.

Pressures and flows will be as above or coil lengths should be suitably adjusted.

At 36,000 B/D, Coil A must be bypassed entirely; this is not included in the automatic control.

Two-pump operation of the line, while calculated in the hydraulics of Table F-I, is considered undesirable and provision for automatic control at that level of operation is not recommended.

36,000 B/D in JP4 requires almost no restriction to flow at Campbell, and is assumed to be necessary only in emergency so that no provision is suggested for making this operation automatic, and the bypass across Coil A will need to be hand operated, and reclosed when normal pumping rates are resumed.

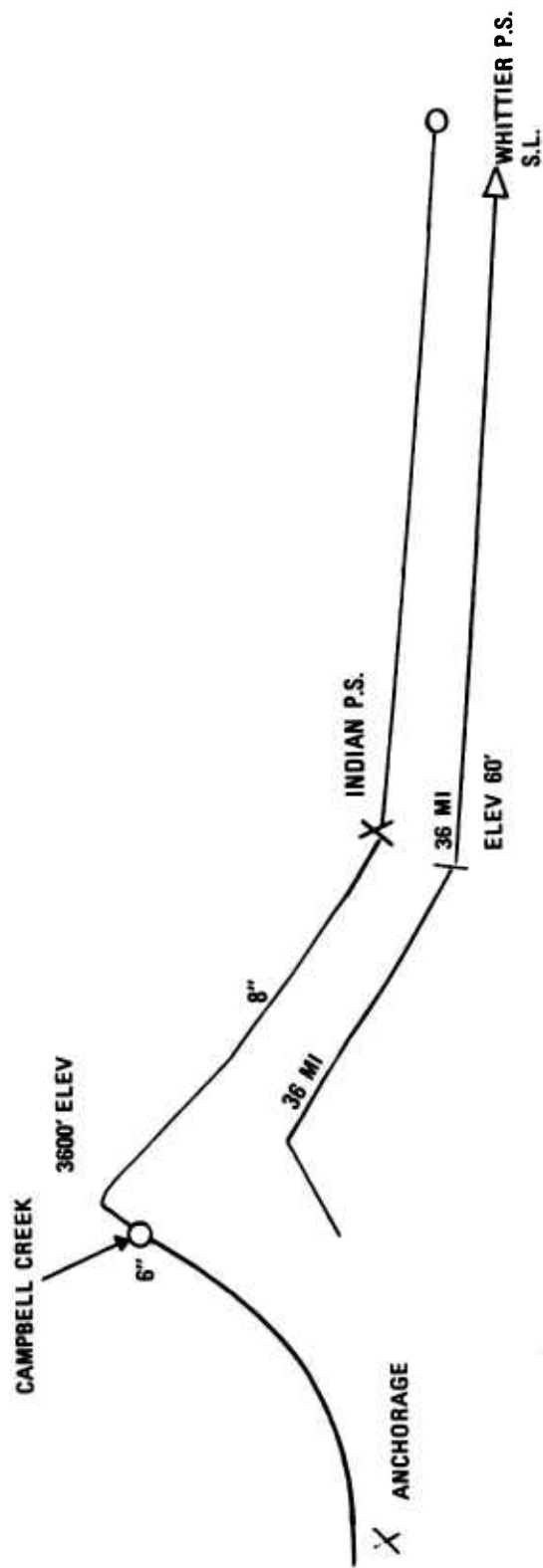


Fig. F-3. Profile of pipeline from Whittier to Anchorage.

## **APPENDIX G**

### **OPERATION OF PRESSURE-REGULATING STATION WITH ACCOMPANYING SCHEMATIC SKETCH**

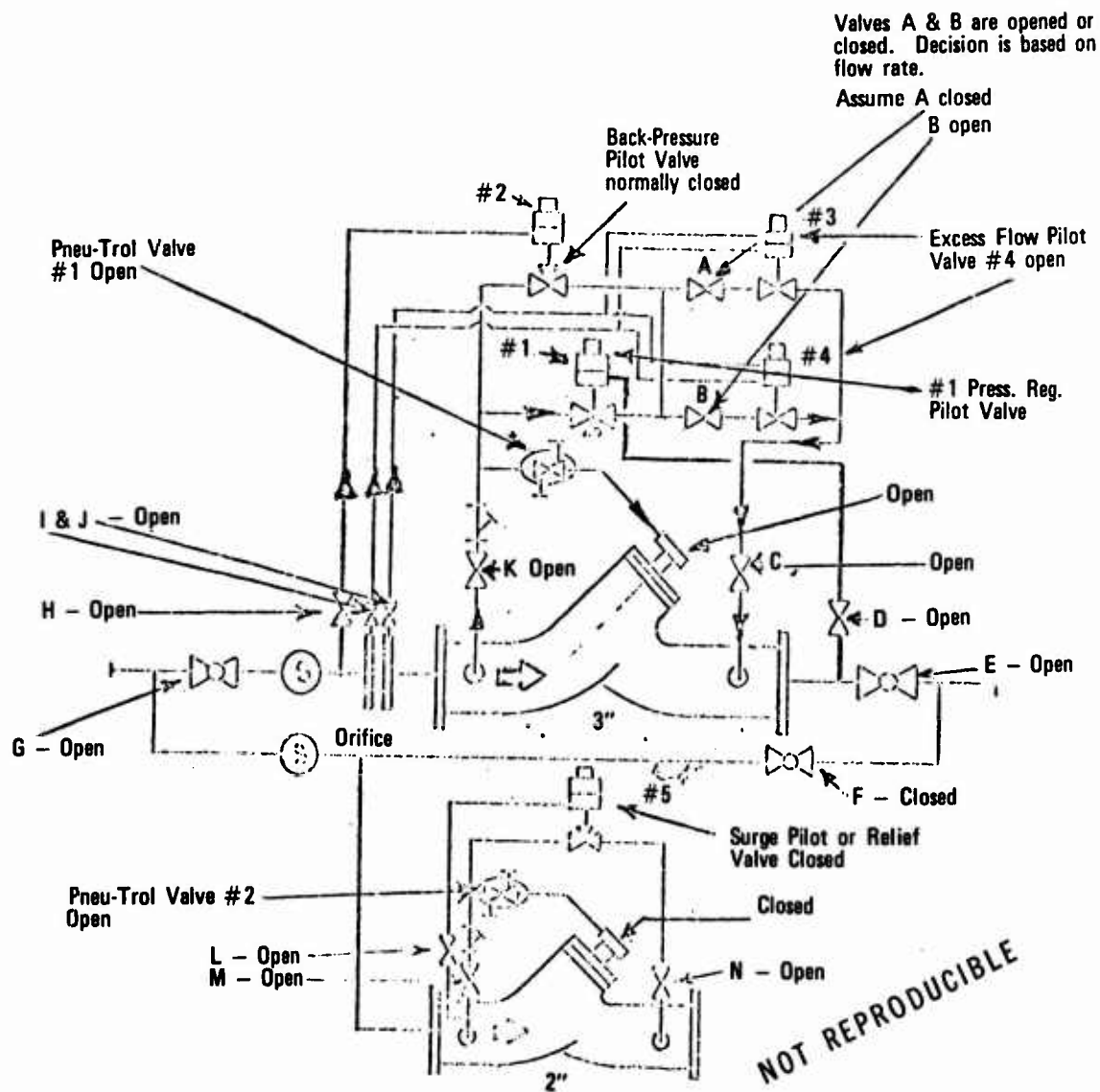
1. Figure G-1 shows positioning of pilot valves, 2-in. and 3-in. control valves, Pneu-Trol valves, gate valves, and ball valves during normal flow conditions.

2. In case of a line break downstream the excess-flow pilot No. 4 will close increasing pressure on piston of 3-in. control valve; it will, in turn, close and remain so until manually reset. The surge or relief pilot valve (No. 5) in conjunction with the 2-in. control valve then protects the pipeline upstream from overpressurization.

3. During shutdown the pressure-regulating pilot valve (No. 1) will be closed as well as the 3-in. control valve. In the event pressure increases upstream due to thermal expansion the back-pressure control valve No. 2 will open, decreasing the pressure on the piston of the 3-in. control valve allowing it to open and relieve the increment in pressure.

4. In the event of a human error such as leaving ball valve G closed during start-up, back-pressure pilot valve malfunctions, a case where the mainline block valve at a pressure-reducing station should remain closed or after running scrapers, etc., additional line protection is afforded by the combination of the surge or relief pilot valve No. 5 and the 2-in. control valve. If any of these conditions would occur then the pilot valve No. 5 would sense the increase in pressure and open. This would decrease the pressure on the piston in the 2-in. control valve and it would open and allow product to pass into a collapsible tank or french pond.

The Pneu-Trol valves No. 1 and No. 2 are to adjust the sensitivity of the piston-type 2-in. and 3-in. control valves to pressure changes.



Above Figure shows positioning of valves during normal flow conditions.

Fig. G-1. Pressure-regulating station—flow schematic.